THE NOVEMBER

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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1934

SOIL EROSION—A NATIONAL MENACE

By H. H. BENNETT

DIRECTOR, SOIL EROSION SERVICE, DEPARTMENT OF THE INTERIOR

UNRESTRAINED soil erosion is rapidly building in this country an empire of worn-out land. The cost of this evil to our farmers and ranchers amounts to at least $400,000,000 annually, to say nothing of the enormous damage to highways and railways and the costly silting of reservoirs, streams and ditches. This appalling wastage is speeding up with the washing off and blowing off of the absorptive topsoil, down to less absorptive, less productive, more erosive subsoil. Over this erosion-exposed material, usually consisting of comparatively impervious clay, rainwater flows away faster from millions of denuded acres to increase the frequency and volume of floods.

At least three billion tons of soil material are washed out of the fields and pastures of America every year. To load and haul away this incomprehensible bulk of rich farm soil would require a train of freight cars long enough to encircle the earth thirty-seven times at the equator. More than four hundred million tons of solid matter are dumped into the Gulf of Mexico every year by the Mississippi alone, along with many more millions of tons of dissolved substances. These materials come largely from the farms of the Mississippi Basin. The greater part consists of super-soil—soil richer than that of the Nile. But the sediments entering the oceans represent merely a fraction of the soil washed out of fields. The greater part is piled up along lower slopes, where it is not needed, or it is deposited over stream bottoms or laid down in channelways and reservoirs. Once the soil leaves a field, it is as irretrievably lost as if consumed with fire, in so far as pertaining to the field from which it is washed. It can not be economically hauled back, even that which is temporarily lodged not far down the slope.

Thousands of farmers operating on slopes stripped of the more productive surface layer have but the slimmest opportunity to make a satisfactory living, whether prices are up or down. They have been lowered to the discouraging level of cultivating land whose productivity has been reduced from two to ten times or more by this tragic wastage, most of which could have been prevented. We find them, generally, not along the main highways, but in the back country, housed in miserable dwellings and living pitifully inadequate lives, with their system of cultivating little plots of ground scattered between gullies and abandoned fields.

WHOLESALE LAND WRECKAGE

Already, the nation has permitted the essential destruction of an area of formerly cultivated land that exceeds the combined extent of Illinois, Massachu-

setts and Connecticut. This is the equivalent of about 220,000 farms of 160 acres each. In addition, this washing of sloping fields has stripped off all or the greater part of the productive topsoil from 125 million acres of the land at present in cultivation; and now, wind erosion is rapidly developing other enormous areas of poor land, as well as destroyed land in our semi-arid belts.

Man's activities in subduing the forests of eastern America, then the prairies to the west and finally the plains, valleys, mountains and intermountain basins beyond, have proceeded along lines of reckless land use. So vast were our original resources in land that no one was concerned with matters pertaining to soil conservation. But now the country may as well gird its belt for continuing battle against this process of land wastage, if we are to avoid the ominous eventuality of becoming the world's most outstanding nation of subsoil farming—which means, generally, submarginal farming, with all its attendant evils of poverty, declining social and economic values and a hopeless outlook upon life.

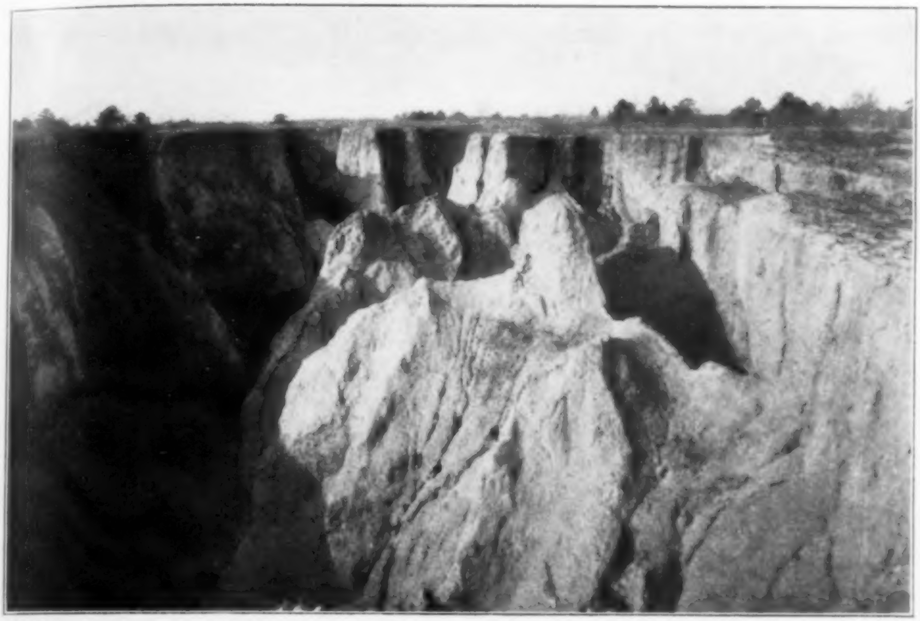
A NEW AMERICAN EXPERIENCE

On the eleventh day of May this year the sun was blotted out over a vast area of northeastern United States by a huge dust storm that originated in the drought-stricken wheat fields west of the Mississippi. This "dry blizzard" of sun-obscuring yellow dust, which swept an estimated bulk of three hundred million tons of rich soil from the sun-parched lands of the Great Plains, marked a stage in our system of land use that should alarm and arouse every thinking citizen. It was a thing that never before happened in America, at least, not since the coming of white men. It was a historic event of far more significance with respect to the continuing welfare of the country than most of the incidents included in our histories.

FIRST STEP IN CONTROL OF EROSION

BY SOIL EROSION SERVICE ON THE SOUTH TYGER RIVER PROJECT, SOUTH CAROLINA. FOLLOWING THE INSTALLATION OF THESE CHEAP LOG DAMS, VEGETATION IS SET IN THE GULLIES AND BETWEEN THE GULLIES. SUCH SORE SPOTS MUST BE CONTROLLED IN ORDER TO PROTECT GOOD FARM LAND ON SLOPES BELOW.

This onward sweeping dust cloud was not the result merely of an unprecedented set of seasonal conditions. For untold centuries droughts have characterized the Great Plains region. The very physical features of the land have been fixed by this climatic factor (the "caliche" or *mid-latitude pedocalic* soils, for example). The wind which



WHAT EVENTUALLY HAPPENS IF GULLIES LIKE THOSE IN THE PHOTOGRAPH ON PAGE 386 ARE NOT CONTROLLED

FORESTED VIRGIN LAND DAMAGED BY GULLIES

THAT STARTED IN AN ADJACENT HIGHER-LYING FIELD. SPARTANBURG COUNTY, SOUTH CAROLINA.

drove that stupendous bulk of soil material half way across the continent was not one which in itself could have accomplished the gigantic task. The real cause was man-induced, speeded-up soil erosion resulting from agricultural utilization of those dry-land areas, plus, of course, a high degree of ground desiccation and soil-lifting winds. Formerly, a natural cover of grass stabilized the ground against wind movement. When this cover was broken, first by farmers venturing beyond the prairies and later by large-scale wheat producers, with their tractors and combines, the loosened soil was laid bare to the driving force of the wind. Its natural firmness was further diminished by continuing cultivation, accompanied by dissipation of the vegetable matter in the soil and the breaking down of the natural structure of the soil—its granularity and fragmental character. Thus, man with his plows and crops developed an incoherent, powdery soil condition favoring the ready lifting of the finer particles into the high pathways of air currents and the leaving of the coarser infertile grains to drift at lower levels by a process of saltation, thus to cover productive land with relatively unproductive wind-assorted material.

This is the simple physics of the process of land stripping by wind, as it is also, essentially, of the still more powerful soil-transporting force of rainwater. It is not an expression of opinion, but a technically determined fact.

Erosion by Water the Major Evil

Land impoverishment by rainwash is an even more serious economic problem than that of wind erosion. The erosion problem in its entirety is a national problem, the economic gravity of which outstrips any of the temporary worries about which we have heard so much recently. But the nation has not yet realized this fact.

What has happened in Stewart County, Georgia, is an excellent illustration of the destructiveness of man-induced erosion. Approximately one fourth of the area of that county—70,000 acres—has been permanently destroyed by gullying. Originally most of this destroyed area consisted of the

THE ONLY HOPE FOR GULLIED LAND OF THIS KIND IS FORESTRY

UNDERCUTTING TYPE OF GULLY

THE KIND MOST DIFFICULT TO CONTROL. HERE CLAY SOIL IS UNDERLAIN BY SOFT, DECOMPOSED GRANITE WHICH CUTS OUT WITH EVERY HEAVY RAIN CAUSING THE SOIL ABOVE TO CAVE IN. SOUTHERN PIEDMONT REGION.

best farm land in the great coastal plain section of that state. There is no practical means by which these devastated lands can be rehabilitated, and the wastage is marching steadily ahead through the remaining areas of good land, of which there is none too much now.

Some of the gullies have cut to depths of 200 feet. One of these has engulfed a schoolhouse, two farm buildings and a graveyard with 50 graves. Thus, the intermingled débris of wasted land, human habitations and the contents of tombs that were supposed to be the peaceful resting places of man have set out upon a journey of death down the valley of the Chattahoochee River, towards the wastes of the Gulf of Mexico.

The 70,000 acres of land destroyed by erosion in this single Georgia county represent but a fraction of the gigantic stride America has made in the direction of land misuse and consequent land impoverishment and destruction. It is merely an example of the appalling cost of unplanned, haphazard, reckless use of the nation's most indispensable resource—the kind of use that falsely presupposes limitless and inexhaustible supplies of good agricultural land.

Erosion Not a Local Problem

Soil wastage by erosion is by no means restricted to the southern states. It has extended to the shores of California and to the very heart of the great Southwestern grazing region. In southwestern Wisconsin and parts of Iowa, Missouri, Kansas and other central states the rate of soil removal by unrestrained rainwater flowing down across unprotected slopes, has been even faster than in the old sections of the East and South, although not so large an area has been ruined as yet. For example, according to actual measurements, the principal type of corn soil on about the average slope (8 per cent.) of the north Missouri-south Iowa section of the corn belt is losing soil where corn is grown

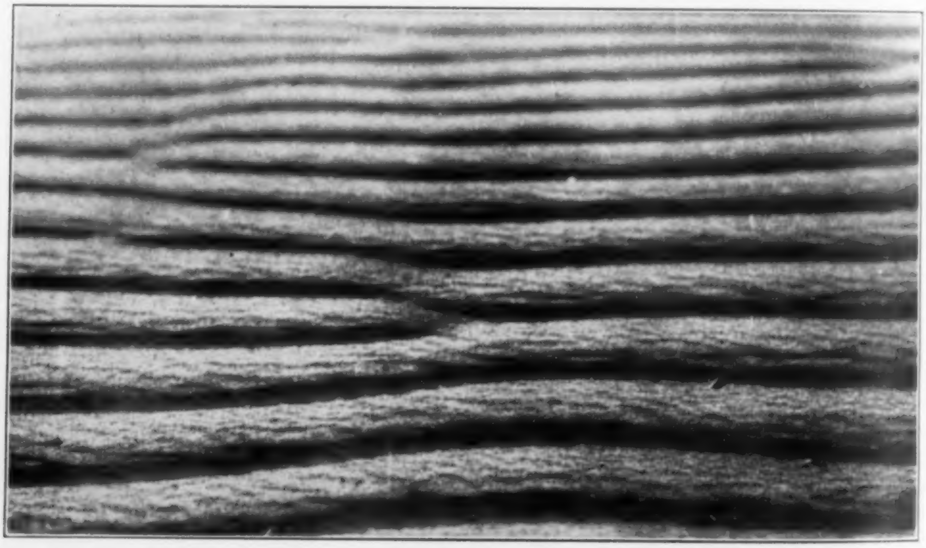
continuously at the destroying rate of 60 tons per acre annually, and with this 27 per cent. of all the rainfall is immediately lost as runoff. This means that the entire depth of the more productive topsoil (about 7 inches) is swept off in approximately 20 years. On the other hand, on exactly the same type of land, occupying the same degree of slope, and receiving the same rainfall, only two fifths of a ton of soil is lost annually per acre where alfalfa is grown and only a little more where timothy grass is grown. The water loss from alfalfa fields is at the rate of only 3 per cent. of the total rainfall. In other words, a thick soil-saving crop like alfalfa is 300 times more effective than a clean-cultivated crop like corn, with respect to conservation of soil. Also alfalfa causes the absorption of 9 times as much of the rainfall as continuous corn.

The average results of measurements made on 12 markedly different and very important agricultural soils, lying largely in the Mississippi Basin, show that grass and similar crops are about 65 times more effective with respect to soil conservation and 5 times more effective with respect to immediate absorption of rainfall than clean-tilled crops grown on the same soils under identically the same conditions as to slope and rainfall.

The Origin of a National Misconception

Immigrants to the American continent found a region so rich in land, timber, grass, game, fish, fur and navigable streams that there early developed in this country a false concept of inexhaustible resources. Unfortunately, this concept has persisted until to-day.

Except in an unimportant way, the Indians had done little to cultivate the soil or to change the virgin character of the land surface and the vegetation on it. The streams bore oceanward the residue of rainwater flowing gently from wooded and grass-covered slopes. Rivers ran clear, except in high flood.



WIND RIPPLES WHICH FORM IN THE DUST PILES FORMED BY WIND EROSION

The ripples average about 2 inches in height and are 4 or 5 inches across. South Dakota, summer of 1934.

HOW WIND EROSION AFFECTS A FIELD
SOUTH DAKOTA, SUMMER OF 1934.

Into this virgin paradise entered the enthusiastic colonists. There began a transformation of the land surface at a rate probably never before occurring in the earth's history, and with it the creation of a nation of fabulous wealth. Reservoirs of population in Europe supplied in a comparatively short time millions of vigorous people to clear away the forests and to break out the prairies in their westward march of agricultural occupation. Frontiers were pushed farther and farther westward at a pace that eliminated planning, or discriminative use of the virgin land, or even thought of the effect of man's activities upon the abundant resources that everywhere swept to far horizons. Man was busy "subduing the wilderness," slaughtering the buffalo for their hides and plowing up the matted sod of the prairies. There seemed no necessity for even thinking of conservation in any form or degree.

Lands which had been thoroughly protected through thousands of years of time by unbroken mantles of vegetation were suddenly exposed over extensive areas to the dash and sweep of torrential rains. Topsoils were literally swept away, leaving raw subsoil exposed at the surface. So stupendous has been the work of this man-induced washing of the land as to reduce and destroy the productivity of millions of acres in numerous densely populated localities within less than a century. The economic and social aspects of this transformation have been tremendous.

Throughout the nation continuing erosion has carried with it consequences of first importance with respect to permanence of investment in the billions of dollars in navigation, power, municipal water supply, irrigation developments, farming and grazing. Products of surface wash and gully excavation have been carried by storm waters to be deposited in stream channels and reservoirs. Yawning gullies have concentrated rainfall in a manner to pass on to streams with greatest possible speed the downpours that gather on watersheds, to gorge the channelways of tributaries and trunk streams with destroying floods. Especially significant is the rapid rate of silting which is going on in reservoirs located on streams within critically eroding areas of the country, both in the East and in the West.

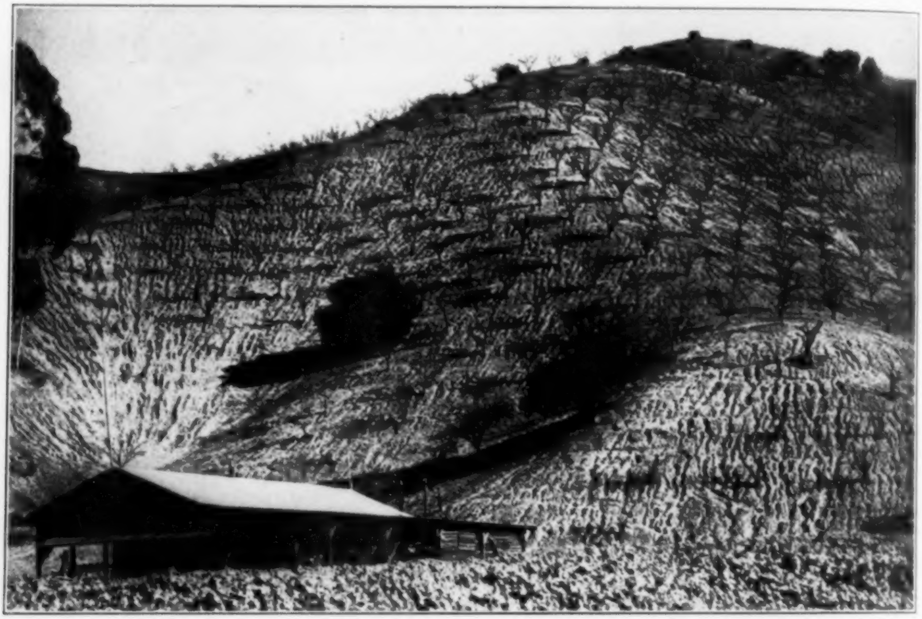
America faces alternatives in this respect. One is to let continue the process now destroying the productivity and utility of millions of acres and adding

annually to a bankrupt domain which is becoming an increasing burden upon counties, states and the Federal Government. Such a way out is not pleasant to contemplate. The other alternative is to diagnose the situation, take full account of the significance and the trend of destructive processes of soil wastage, increasing runoff and sedimentation of reservoirs and stream channels, to relate these to all types of practical land use within drainage basins and to control and reduce these processes to a rate as nearly as may be practicable to the rates that existed when white men found so much of the country covered with unbroken vegetation.

At the Crossroads

The nation may as well realize now that it has a land crisis on its hands—the problem of man-accelerated soil erosion, and that every stroke of work performed in opposition to this evil adds value to our most basic resource—that resource which offers the last safe refuge for numerous families thrown out of employment through increased use of machinery, and that resource which after all is the principal security behind our national investments, our national safety and our national future. Beyond this most acute crisis of the whole land problem, the country may as well recognize now the physical fact, not an expression of opinion, that there can be no cure of floods or prevention of stream and reservoir silting until runoff is better controlled, all the way from the crests of ridges down across the watersheds where floods originate and silt loads are picked up, on to the very channelways of streams, which like other conduits have limitations upon their carrying capacity.

Over many millions of acres a long



VIOLENT EROSION IN A STEEP, CULTIVATED APRICOT GROVE OF SOUTHERN CALIFORNIA

THE RESULT OF A HEAVY RAIN ON FEBRUARY 23, 1934. THE LOSS OF SOIL PER ACRE AMOUNTED TO 400 TONS. THERE WAS NO EROSION ON THE SAME FARM WHERE LAND OF THE SAME DECLIVITY WAS PROTECTED WITH NATIVE VEGETATION, NOT OVERGRAZED.

WIDENING CHANNEL OF PUEBLO COLORADO WASH

INCREASING FLOOD WATER RUSHING DOWN FROM THE DENUDED OVERGRAZED RANGES IS STEADILY CUTTING AWAY THE RICH ALLUVIAL DEPOSITS OF THIS VALLEY, THE FORMATION OF WHICH TOOK THOUSANDS OF YEARS. JUST ABOVE THE TRADING POST OF GANADO, NAVAJO INDIAN RESERVATION, ARIZONA.

FORMER GRAZING LAND

REDUCED TO ESSENTIAL STERILITY BY EROSION FOLLOWING OVERGRAZING, AT SANASTEE, NEW MEXICO, NAVAJO INDIAN RESERVATION. THE SOIL AND SUBSOIL HAVE BEEN WASHED OFF DOWN TO "ALKALI" MATERIAL, ON WHICH IT IS EXTREMELY DIFFICULT TO INDUCE ANYTHING TO GROW.

VEGETATION ON ALLUVIAL SOIL

OF A TRIBUTARY TO SAN SIMON WASH, GRAHAM COUNTY, ARIZONA. THIS AREA HAS BEEN PROTECTED AND REPRESENTS AN APPROXIMATION OF THE ORIGINAL CONDITION OF VEGETATION, SUCH AS CHARACTERIZED SAN SIMON VALLEY PRIOR TO THE CUTTING OUT OF THE IMMENSE WASH EXISTING THERE NOW—SINCE THE ARRIVAL OF THE WHITE MAN WITH HIS HERDS OF LIVE STOCK THAT OVERGRAZED THE UPLANDS.

ERODED CONDITION FOLLOWING OVERGRAZING

SAN SIMON VALLEY, GRAHAM COUNTY, ARIZONA. THIS AREA, NOW ESSENTIALLY DESTROYED, WAS FORMERLY COVERED WITH A THICK COVER OF VEGETATION LIKE THAT IN THE UPPER PHOTOGRAPH.

time was required to strip off the highly absorptive topsoil, down to stiff clay of low absorptive capacity; but now that this has been accomplished, and since the surface layer is rapidly being removed from additional millions of acres, the battle is definitely on, and with no secure second lines upon which to fall back.

We have a tremendous area of land in this country, but it is not all good land. Unfortunately, the remaining areas of good agricultural land are being cut into at a rate of probably considerably more than 100,000 acres destroyed every year and a much larger area sorely impoverished by the effects of sheet-washing proceeding with every rain heavy enough to cause water to run down across unprotected cultivated and overgrazed slopes. Most of us have seen the process in action, although without understanding it, and, therefore, without being concerned about it. Few have undertaken to interpret the phenomenon witnessed after every summer rain in the form of muddy waters coursing down gullies, creeks and rivers in the direction of the oceans. We have not stopped to consider that the material discoloring these unleashed waters consists of soil or that this material is derived chiefly from the surface of the ground, where lies the richest part of the land. Probably also most of us have not considered a number of other pertinent matters relating to this never-ending process. Have we considered, for example, the fact that the average depth of humus-charged surface soil over the uplands of the United States is only about seven or eight inches? Have we considered the further fact that beneath this surface layer, the building of which required the best efforts of nature's soil-forming processes over periods of thousands of years, generally lies raw clay subsoil which is not soil but the material from which soil is made, not in a few years but across the centuries? Have we been concerned that this exposed subsoil not only is from two to more than ten times less productive, generally, than was the cor-

CONTOUR FURROWING

TO CHECK EROSION OF OVERGRAZED PASTURE ON SOIL EROSION PROJECT, WATERSHED OF ELM CREEK, CENTRAL TEXAS. PHOTOGRAPHED IN 1934.

RICH BLACK LOAM

AND THE CORN ON IT BURIED 4 FEET DEEP IN PLACES BY SAND WASHED OUT OF A NEARBY GULLY DURING A SINGLE SEASON. ROOT RIVER VALLEY, HOUSTON COUNTY, MINNESOTA.

responding topsoil; that it is more impervious to rainwater, is more difficult and costly to plow, and, what is exceedingly serious, that it is more erosive usually than the sponge-like surface layer? With most of us the answer unfortunately is a very decidedly negative one.

ROCK-FILL DAM

WITH ROCK SAUSAGE CAP CONSTRUCTED BY SOIL EROSION SERVICE IN HAWK HOLLOW WASH, GRAHAM COUNTY, ARIZONA, IN 1934.

Few people (scientist, economist or layman) know that it is at the stage of progressive erosion, marking the removal of the topsoil (the farmers' principal capital) that gullying usually sets in, or that gullying represents the beginning of the death stage of land—its final and complete destruction. This important fact, and many others, the average person knows little about.

Control of Erosion an Unavoidable Necessity

Control of erosion is the first and most essential step in the direction of correct land utilization on something like 75 per cent. of the cultivated (and cultivable) area of the nation. If the soil is permitted to wash to a condition equivalent to skeletonized land, as has happened already over something like 35 million acres formerly cultivated, there will be nothing left to save. Failure to curb this insidious process will effectively and disastrously take care of all aspects of the land problem in numerous localities, both physical and economic; and after this deluge of waste, nature, in numerous instances at any rate, can do as good a job as man with the rehabilitation of the hopelessly devastated areas through the instrumentality of whatever vegetation comes in spontaneously.

It seems scarcely necessary to add that whatever our inclinations may be, whatever opinions, conclusions or complexities our round-table, institute and academic discussions may lead us to, here assuredly is a physical job—the job of curbing erosion—that must be performed if the nation is to avoid early arrival at an inconceivably bad land situation. The Union of South Africa has reached this conclusion and is now busily engaged in an attack against the devastating erosion of that country, employing a plan of procedure very much like that developed by the Soil Erosion Service (as described below). The

Italian Government is engaged in an enormous land reclamation and conservation program—the Bonifica Integrale—the cost of which has been estimated at $500,000,000. Japan for many years has been spending many times the value of numerous critically eroding areas in order to protect indispensable valley lands from the silt issuing from such sore spots. The United States can no more afford to neglect any further this gigantic problem of waning soil productivity than South Africa or Japan or Italy, for the very simple reason that we are depleting our farm and grazing lands at a rate probably exceeding that taking place on any other important part of the globe.

Average Crop Yields Not Increasing

Regardless of our highly successful results with breeding more productive strains of crops and the introduction of new and better varieties from the ends of the world; in spite of the improved cultivation performed with more and better machinery, the increased practise of soil-building rotations and the growing of more soil-improving plants, the largely increased use of fertilizers and plant disinfectants; and further, in spite of all the education provided through our agricultural colleges, agricultural societies, clubs and institutes, soil surveys, economic surveys, experimental and extension services, farm journals, the press, thousands of books and millions of bulletins, with frequent prizes for the best producers, *our nation-wide yields have not increased—rather they have decreased in the instances of some of our major crops.* For example, the annual acreage yield of corn for the 10-year period from 1871 to 1880 was 27.04 bushels per acre; whereas, for the 10-year period from 1921 to 1930 the corresponding acreage production was 26.13 bushels, or a reduction of approximately one bushel an acre. That the maximum and minimum yields for single years during the former period were higher, respectively, than the maximum and minimum yields of the latter period indicate that the comparisons are significant.

When it is considered that corn growing has not been pushed onto the marginal and submarginal lands of semi-arid regions upon any extensive scale, and that the crop has not suffered from any

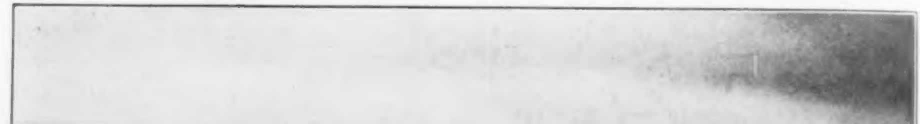
EROSION MONOLITHS

IN PROVIDENCE CAVE, STEWART COUNTY, GEORGIA. THESE LOFTY PINNACLES ARE REMNANTS OF A FORMER HIGHLY PRODUCTIVE COTTON FIELD. THEY STAND IN A GULLY WHICH WAS BEGUN BY THE DRIP FROM THE ROOF OF A BARN, ABOUT FIFTY YEARS AGO. THE GULLY HAS CUT DOWN 200 FEET AND HAS SWALLOWED UP THE BARN, A SCHOOLHOUSE, A GRAVEYARD AND SEVERAL TENANT HOUSES. IN THE COUNTY WHERE THIS PICTURE WAS TAKEN 70,000 ACRES OF LAND, ONCE HIGH-GRADE FARM LAND, HAVE BEEN PERMANENTLY DESTROYED BY UNCONTROLLED EROSION. EVERY ACRE OF THIS COULD HAVE BEEN SAVED.

far-reaching, devastating insect or disease scourges, it is impossible to reach any other than the definite conclusion that erosion has thwarted our stupendous technical, educational and practical efforts to increase the yield of this crop.

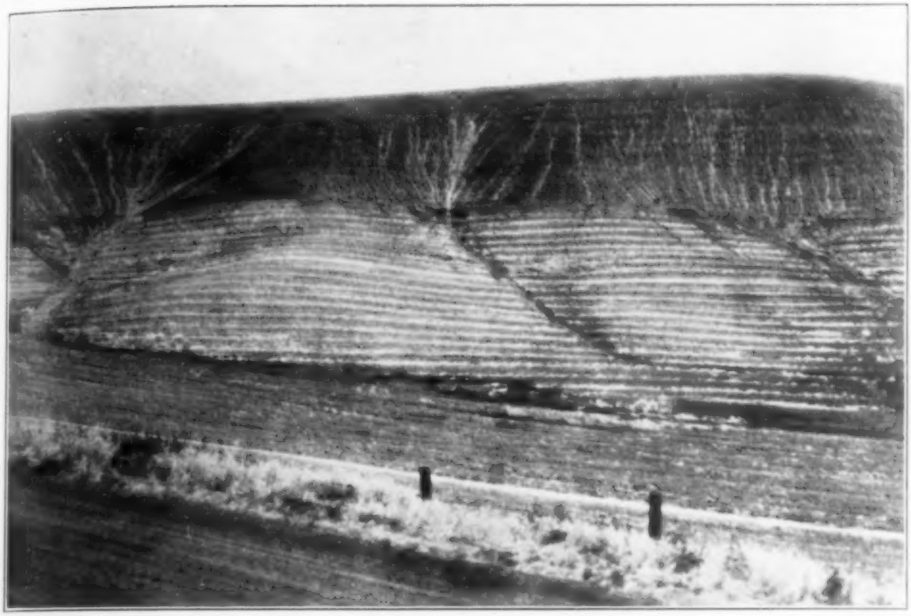
A Major Effort at Erosion Control

During the latter part of 1933 the Soil Erosion Service was set up as a new branch of the Interior Department, with an allotment of $10,000,000 from Public Works Administration for the purpose of demonstrating the practical possibilities of curbing erosion and its allied evils of increased floods and costly silting of stream channels and reservoirs, operating within the various important geographic and agricultural regions where these evils are known to constitute major problems in connection with the use of the nation's resources of land and water. The general plan of procedure, as suggested by the President, is to treat complete watersheds within which the principal regional types of soil, average regional topographic conditions and representative regional systems of agriculture are found. The individual size of these watersheds, of which 21 are now under treatment in 20 states, ranges from 25,000 to 200,000 acres. The accompanying map shows the location of these watershed areas, and that of the huge project covering the Navajo Indian Reservation in Arizona, New Mexico and Utah; as well as several other projects and proposed projects of an experimental-demonstrational character. Altogether, the Soil Erosion Service is now actively engaged in combatting erosion and its associated evils of stream and reservoir silting, in-



SOIL WASHED DOWN OVER A SNOWBANK

BY THE MELTING OF SNOW ON SUMMER-FALLOWED LAND ABOVE, IN THE PALOUSE REGION, SOUTHEASTERN WASHINGTON.



SEVERE EROSION ON SUMMER-FALLOWED UPPER SLOPE

BY MELTING SNOW, WITH NO EROSION IN OLD WHEAT STUBBLE BELOW, IN THE PALOUSE WHEAT BELT, WASHINGTON STATE, 1934.

creasing floods, social disorganization and wild-life depletion, on approximately 27 million acres located in 27 states.

Plan of Procedure

The method of attack is essentially a coordinated plan of correct land use. This plan involves not only the use of direct methods of retarding erosion (which necessarily calls for retardation of runoff by increasing absorption of the rainfall), but the use of indirect methods, such as the retirement from cultivation of steep, highly erosive areas from which accelerated runoff (resulting from incorrect land usage) descends with destructive effect upon lower-lying cultivated areas. Such retired critically vulnerable lands are being planted with thick soil-holding crops, as trees, grass, alfalfa, lespedeza, sorghum and clover.

Part of the cultivated land is being protected with the new system of strip-cropping, under which the clean-tilled crops, such as cotton, corn and tobacco (the real producers of erosion) are being grown between parallel bands of grass, lespedeza, sorghum and other dense crops planted across the slopes, on the level, *i.e.*, along the contours. These latter crops catch rainwater flowing down the slopes, spread it out and cause the suspended soil to be deposited and much of the water to be absorbed by the ground, thus protecting the crops growing on the plowed strips below. On certain slopes strips of permanent protective cover will be planted according to the French system, using trees, shrubs and vines. Here is an opportunity to make advantageous use of nut trees, persimmon, honey locust (producing feed for livestock), briar crops and other plants of economic value. It is hoped that it may be possible on some of the project areas to employ the Ecuadorian system of protecting steep slopes by bordering the down-hill sides of rectangular fields with soil-holding hedges.

Field terraces (embankments ad-

justed to the contours) are being employed where applicable, and in some localities it is planned to scarify certain types of land (especially summer-fallowed ground) with a machine which scoops out 10,000 basin-like holes to the acre, each of which retains about five gallons of rain, causing it to sink into the ground where it falls (machines for this purpose are now being manufactured). Soil-conserving crop rotations are being practised, and cover crops and other control measures are being employed.

Every farm is surveyed in advance of actual work, by specialists of the local erosion staff. Soils, slopes and extent of erosion are plotted on accurate maps. With the aid of this, the farmer and erosion specialists go over the farmstead, study it in detail and on the ground plan a course of procedure by assigning each acre to a particular use, in accordance with its needs, adaptability and appropriate place in a carefully planned coordinated land-use program for that particular farm. The work is carried out on a strictly cooperative basis with the farmers. Generally the latter are enthusiastically supporting every phase of the program. On some of the projects more than 95 per cent. of the farmers are going along with the program of the erosion specialists, agreeing to far-reaching reorganization of their fields and farm procedures. For example, on numerous farms fences are being relocated so as to permit contour cultivation, terracing, strip-cropping, the inauguration of soil-building rotations and the planting of the more vulnerable slopes to grass, trees, etc. Such hearty cooperation, it is believed, insures the success of the program. By putting through these initial educational watershed projects in a highly impressive manner, it is felt that it will then be possible to extend the work to all areas through the activities of the Soil Erosion Service, the Extension Service, the colleges of agriculture and other organizations.

First Coordinated Erosion-Control Effort

Here is the first attempt in the history of the country to put through large-scale, comprehensive erosion and flood control projects, such as apply to complete watersheds from the very crest of the ridges down across the slopes to the banks of streams and thence to their mouths. These are not engineering projects or forestry projects or cropping projects or soils projects or extension projects, but a combination of all these, operated conjointly with such reorganization of farm procedure as the character of the land indicates as being necessary. This procedure is based on the best information in the possession of scientific agriculturists: agronomist, forester, range specialist, soil specialist, erosion specialist, agricultural engineer, economist, extension specialist, game specialist and geographer. It is the application of accumulated knowledge pertaining to the great multiplicity of variables affecting the 3-phase process of absorption, runoff and erosion, employed not as single uncoordinated implements of attack, but collectively, according to the needs and adaptability of the land, in a combination of integrated control measures, supplemented by new information accruing from the experience of combat. No such coordinated attack has ever before been made against the evil of erosion in this country. The plan was worked out largely on the basis of the writer's many years of experience in the study of soils and of land-use procedure in the United States, the West Indies and Central and South America; plus the experiences of other specialists familiar with the land and its utilization. Considering the physical, economic and social factors involved, it is believed there is no other possible practical method of ever mak-

RESERVOIR FILLED WITH EROSIONAL DEBRIS

TO THE TOP OF THE DAM (BUT NOT TO THE TOP OF THE FLASHBOARD EXPEDIENT ON TOP OF THE STONE MASONRY FOR MAKING SOME LAST, SHORT-PERIOD USE OF THE COSTLY STRUCTURE). PACOLET RIVER, 7 MILES NORTH OF SPARTANBURG, SOUTH CAROLINA.

ing any effective headway against this vicious problem (1). Even if the government owned the land, it would still have to be used over large areas in the production of crops and for grazing; and here again precisely the same physical problems would have to be met and conquered, an eventuality that unavoidably precedes all other consideration relating to correct land use.

Examples of Procedure

In the Wisconsin erosion project (covering Coon Valley, near La Crosse), for example, some of the steep timbered areas, now eroding because of excessive grazing, are being taken out of use and given complete protection in order to stop the excessive runoff of rainwater, which has been speeding down across the cultivated slopes, ripping them to pieces with gullies or planing off the more fertile topsoil. Grass is being restored to these protected forest areas, and where the trees are too thin other trees are being planted. Small plantings and seedings are being made that furnish feed and cover for quail and ruffed grouse. Eventually, with increased stocks of these fine game birds, saved from starvation during prolonged periods of snow, as was done last winter, sportsmen will come from Milwaukee, St. Paul, Chicago and other places to pay the farmer for the privilege of hunting in his timbered lands.

Below the forested land, the steep slopes now washing rapidly to a condi-

AIR PICTURE OF APPROXIMATELY 1,000 ACRES

SHOWING BOTH GULLY AND SHEET WASHING. ALL THE TIMBERED LAND WAS FORMERLY CULTIVATED AND THEN ABANDONED BECAUSE OF EROSION. THE TREES (DARK-COLORED AREAS) ARE SECOND-GROWTH PINE (OR THIRD- OR FOURTH-GROWTH PINE, DEPENDING ON HOW MANY TIMES THE LAND HAS BEEN CLEARED, CULTIVATED AND RE-ABANDONED). MOST OF THE LAND IS NOW ESSENTIALLY RUINED AND CAN BE PUT TO USEFUL PURPOSE ONLY THROUGH TREE AND GRASS PLANTING. SOUTH TYGER RIVER PROJECT OF SOIL EROSION SERVICE, NEAR SPARTANBURG, SOUTH CAROLINA.

tion of low productivity are being taken out of the clean-tilled crops and put into permanent pasture to furnish the grazing that formerly was provided by the timbered areas. The grazing capacity of the farms is not thus increased or materially decreased, but the crop area is cut down to some extent. Better protection of the cultivated land from erosion will largely make up for this reduction, by way of higher acreage yields.

On the 150,000-acre watershed erosion project on Big Creek in north-central Missouri, extending into south-central Iowa, a report of progress submitted by the regional director of the soil erosion work, under date of June 23, 1934, includes the following highly pertinent statement with respect to accomplishment (work having begun on this area in the spring of 1934): "At this time we have 401 cooperative agreements signed up with the farmers of the Big Creek project, and over 63,000 acres of land under contract for a coordinated plan of erosion treatment. We have been successful in reducing the corn acreage over the next 5-year period by more than 37 per cent. on these farms. We have cut the acreage of land where corn follows corn for a second year (a very bad practise) more than 54 per cent. We have

very materially increased the acreage of pasture. We are planning an intensive program on pasture improvement, beginning this fall and continuing into next spring. While weather conditions have been quite unfavorable, it is felt that very good progress has been made to date."

Thus, all indications point to successful achievement with these coordinated, educational programs of erosion control —which, it should be emphasized in conclusion, are of an experimental-demonstrational nature, and which, by reason of the necessary procedures involved with the accomplishment of a complete job, extend beyond the mere task of controlling erosion.

(1) It seems unfortunate that some single-ideaed (or perhaps under-experienced) specialists still insist that this powerful agency of accelerated erosion can be overcome through the use of single implements of attack. With the pages of experience laid open to eyes that see over millions of acres of land ruined for crop use and more millions impoverished, and with the wastage proceeding faster than ever, it is discouraging to hear these specialists contend, for example, that erosion can be controlled solely with terracing (embankments of earth adjusted to land contours). Most specialists understand clearly that terracing is a very useful method of assisting with erosion control (see "A Proposed System of Erosion Control," *Agricultural Engineering*, V. 14, No. 6, June, 1933, pp. 150–151, by H. D. Sexton and E. G. Diseker). The system was devised about a hundred years ago in the southeastern United States and extensively employed, in several modifications, in that section, often with excellent results. In spite of the usefulness of the method, where properly applied, several million acres on which it was employed have, nevertheless, been abandoned because of continuing erosion. Some forty years ago Priestly Mangum developed on his farm near Wake Forest, North Carolina, a broad-base terrace which was a decided improvement over the older narrow type. This improved type, the Mangum terrace, has been extensively used since its development in various parts of the Southeast, and more recently it has come into quite extensive use in Texas, Arkansas and Oklahoma. Even the Mangum terrace, however, has not, where used alone, succeeded in controlling erosion, except on rather gently sloping land, although it has accomplished much good in slowing down the washing, especially where used on slopes not steeper generally than about 6 or 7 per cent.

Obviously, it is impossible completely to control erosion, a process that begins wherever rainwater contacts bare sloping ground, with

SOIL EROSION CONTROL PROJECTS

any implement which does not cover the entire surface. In other words, erosion goes on between the terraces, as well as on sloping soil exposed between any other installations of contour measures. Soil washes from below the upper terrace embankment to lodge against the next embankment below, where, according to common practise, it is plowed up and partly dumped over the embankment to renew its journey in the direction of tidewater. In this connection it might be added that we have recently been furnished with results of measurements of soil loss from terraced areas, misinterpreted as representing the entire acreage losses for the entire terraced field. Such reported losses were measured by collecting samples of the runoff, and its contained silt, at the ends of terrace embankments. The fallacy of presenting such results as measurements of acreage losses from entire fields is obvious. The simple facts involved are that the measurements represent only the soil that passes out of the field at the end of the terrace, leaving out of account entirely the much greater bulk of material washed from the upper slope of the inter-terrace area down to the lower slope, or into the terrace channel, where it is temporarily lodged and then passed on down the slope through the operations of "terrace maintenance"—as much lost, in so far as its place of origin is concerned, as if immediately dumped into the sea (since it is uneconomical under the American system of extensive agriculture to haul it back into the field). Of course, the temporary lodgement of productive soil material against any obstacle keeps it in the field, or on part of the field, for a while, and so gives some temporary benefit.

Still other features relating to this useful method of combatting erosion should be seriously considered before making indiscriminate use of it, otherwise more damage than good may result. The terraces must be accurately laid out and properly built, as a matter of course; but what is just as important is that they should be limited in their application, when used alone, to comparatively gently sloping areas, for the reason that on steep land larger embankments are required generally and the distance between them must be narrowed. Accordingly, so much of the fertile topsoil of the inter-terrace area goes into the building of the embankment that the land from which this surface material is removed is left poorer, where the soil depth is shallow, than it was, or is likely to be in some instances for generations to come. It must be remembered, too, that in building a terrace the slope is increased quite sharply along the lower side of the embankment, and accordingly susceptibility to erosion is increased at this critical point, unless stabilization is effected with some dense cover of vegetation, as grass.

But when we begin to support one measure with another, especially when we make use of nature's most powerful agency of controlling erosion—densely growing vegetation—as in the instance of stabilizing the vulnerable lower side of a terrace embankment with grass, we have, in that sensible acceptance of a supplemental agency, ceased to be advocates of a false practise—the practise of fighting erosion solely with a single implement, whether it be terracing, strip-cropping or what. It should be pointed out, of course, that, when the ground is completely covered with good stands of grass or trees or other dense types of vegetation, then with a single implement we may have complete or very nearly complete control of erosion (see charts, Trans. Am. Geophysical Union, Nat'l. Research Council, pt. 2, pp. 474-88, 1934, showing comparative soil losses from clean-tilled land and land covered with grass or trees). This paper, however, deals primarily with erosion on cultivated land, where the entire area can not be covered with such control measures.

PROLONGING THE LIFE SPAN

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The preservation of life, the defending of the human body from decay, and of rendering it a fit tenement for the soul to inhabit, in that season in which she is most capable of exerting her noblest faculties, are grave and serious subjects with which no trivial matters ought to mingle.
—*Hermippus Redivivus.*

In this day when both children and animals are being fed to attain a maximum growth rate, it seems little short of heresy to present data in favor of the ancient theory that slow growth favors longevity. A hundred years ago when men first became conscious of the need for the accessory factors which we now term vitamins, the field of nutrition was broad. Students attempted to study the requirements of both adult and growing animals. To-day research has tended to narrow into a channel of primary interest in the young, growing animal. Interest is centered on the growth and apparent health of this animal. After it becomes an adult it is no longer an "apple of the eye" of the nutritionist, but primarily a carcass that provides dissecting material for the pathologist. The nutrition student is too busy pouring vitamins, minerals and proteins into the young and growing to be much concerned with the grown.

The philosophy which dominates the field of nutrition assumes that a young animal which grows rapidly is the ideal for maximum health both during the growing period and during adult life. This philosophy has developed under the influence of several stimulants. In the first place, a young animal such as the white rat, which is the central interest in most nutrition laboratories, grows to maturity in about three months. Studies of the growth of this animal provide opportunities for numerous discoveries in the course of a short-time period. Technical journals are cluttered to-day with thousands of reports concerning the growth of the white rat. But if one tries to discover the length of life of this widely used animal, he will not find five good reports in the entire literature.

A second stimulus to this interest in the growing animal and disregard of the adult is due to the public interest in the young and growing. The healthy adult is a matter of little interest, even to himself, and the sick one usually rates as a pest. This philosophy belongs properly to the butcher. Every producer of meat animals wants to rear them rapidly because it is economical. These animals are killed as soon as they mature. What agricultural expert can tell the effect of the feeding during the growth period upon the milk-producing capacity of a cow during her entire life? What chicken specialist can tell the effect of the rate of growth of the chicken upon the egg production of the laying hen? Who can tell you the effect of the rate of growth of a child upon its susceptibility to disease during adult life? Who can give assurance that the child that matures rapidly will not die after a short life span?

A third stimulus whose importance may be overlooked is that of commercial advertising. While preparing this note I selected at random one of the copies of the *Journal of the American Medical Association,* which is published weekly. More than a fifth of the advertising in this journal was devoted to fortified foods for children, chiefly for defenseless babies that are more or less easily coerced into engulfing various vitamin

concentrates. It must be possible to market such products. Who can estimate the effectiveness of such constant advertising in the *Journal* of the American physician in creating and moulding his philosophy and his recommendations in feeding children? Is it any wonder that the pediatrician has become an advocate of rapid growth? Even the manufacturer of scales does his part by buying space in this same professional journal in order that no one shall neglect to keep his child up to date in weight. Thus has been created an enthusiasm for growth and growth stimulants. And what profit in dollars can be made from any other philosophy?

Before becoming involved in experiments and data it may be well to refer briefly to three philosophers. In his treatise upon the generation of animals Aristotle states:

> The period of gestation is as a matter of fact determined generally in each animal in proportion to the length of its life. This we should expect, for it is reasonable that the development of the long lived animals should take a longer time.

If we turn to the Opus Majus of Roger Bacon (1214–1294) we read:

> Another example can be given in the field of medicine in regard to the prolongation of human life, for which the medical art has nothing to offer except the regimen of health. But a far longer extension of life is possible. At the beginning of the world there was a great prolongation of life, but now it has been shortened unduly.

Further in this same work we read:

> Therefore in regard to this we must strive, that the wonderful and ineffable utility and splendor of experimental science may appear and the pathway may be opened to the greatest secret of secrets, which Aristotle has hidden in his book on the Regimen of Life. For although the regimen of health should be observed in food and drink, in sleep and in wakefulness, in motion and in rest, in evacuation and retention, in the nature of the air and in the passions of the mind, so that these matters should be properly cared for from infancy, no one wishes to take thought in regard to them, not even physicians, since we see that scarcely one physician in a thousand will give this matter even slight attention. Very rarely does it happen that any one pays sufficient heed to the rules of health. No one does so in his youth, but sometimes one in three thousand thinks of these matters when he is old and approaching death, for at that time he fears for himself and thinks of his health. But he cannot then apply a remedy because of his weakened powers and senses and his lack of experience.

In another paragraph Roger Bacon continues:

> Since I have shown that the cause of a shortening of life of this kind is accidental, and therefore that a remedy is possible, I now return to this example which I have decided to give in the field of medicine, in which the power of medical art fails. But the experimental art supplies the defect of medicine in this particular. For the art of medicine can give only the proper rules of health for all ages. For although noted authors have spoken inadequately concerning the proper regimen of the aged, it has been possible, however, for medicine to give such a regimen. This regimen consists in the proper use of food and drink, of motion and rest, of sleep and wakefulness, of elimination and retention, of the air, and in the control of the passions of the mind. But if from birth a man followed a proper regimen to the end of his life he would reach the limit of life set by God and nature, in accordance with the possibility of a proper regimen. But since it is impossible for this regimen to be followed by any one, and since few, nay, scarcely any one at all, from youth pay any heed to this regimen, and very few old people observe it as it is possible, therefore the accidents of old age of necessity come before old age and senility, namely, in the period of the prime of life, which is the age of human beauty and strength. In these times this period of life does not continue beyond forty-five or fifty years.

This scientist and monk of the middle ages continues:

> Not only are remedies possible against the conditions of old age coming at the time of one's prime and before the time of old age, but also if the regimen of old age should be completed, the conditions of old age and senility can still be retarded, so that they do not arrive at their ordinary time, and when they do come

THESE TYPICAL RATS ARE BOTH 900 DAYS OLD

THE ONE ON THE LEFT GREW RAPIDLY AND "NORMALLY" TO MATURITY WHILE THE PHYSIOLOGICALLY YOUNG ANIMAL ON THE RIGHT WAS RETARDED IN GROWTH AND FORCED TO MATURE SLOWLY.

they can be mitigated and moderated, so that both by retarding and mitigating them life may be prolonged beyond the limit, which according to the full regimen of health depends on the six articles mentioned. And there is another farther limit, which has been set by God and nature, in accordance with the property of the remedies retarding the accidents of old age and senility and mitigating their evil. *The first limit can be passed but the second cannot be.*

As every one is well aware, this usefulness of the experimental method in attacking the problems of longevity remained unheeded, as it has to this hour. A few hundred years after these words of Roger Bacon we read the statements of Lord Francis Bacon (1561–1626):

We make the third part of medicine regard the prolongation of life; this is a new part, and deficient, though the most noble of all; for if it may be supplied, medicine will not then be wholly versed in sordid cures, nor physicians be honored only for necessity, but as dispensers of the greatest earthly happiness that could well be conferred on mortals for though the world be but as a wilderness to a Christian travelling through it to the promised land, yet it would be an instance of the divine favor, that our clothing, that is, our bodies, should be little worn while we sojourn here. And as this is a capital part of physic, and as we note it for deficient, we shall lay down some directions about it.

In the light of our experimental data which follow, six of these rules of Lord Bacon may prove interesting:

(1) The cure of diseases requires temporary medicines but longevity is to be procured by diets.

(2) It seems to be approved by experience that a spare and almost Pythagorean diet, such as is prescribed by the stricter orders of monastic life or the institutions of hermits, which regarded want and penury as their rule, produces longevity.

(3) Animals which come later to perfection (I am not speaking of growth in stature only but of the other steps to maturity as man puts out first his teeth, then his signs of puberty, then his beard, etc.) are longer lived for it indicates that the periods return in wider circles.

(4) To grow long and slowly is a sign of longevity and the taller the stature the better the sign. But on the other hand, rapid growth to a great stature is a bad sign but to a shorter stature less bad.

(5) I would have men duly to observe and distinguish that the same things which conduce to health do not always conduce to longevity.

(6) Again there are other things very beneficial in prolonging life yet that are not without danger to the health unless guarded against by proper means.

Finally before considering data it is worth noting some statements from a

more modern work, "La Philosophie et la Longevité," of Jean Finot. In 1906, just as the extensive modern interest in vitamins was taking form, Finot wrote:

> Here is a fact in another type of idea, which has cost the lives of millions of men. From many observations we have learned that the vitality of the world's animals is in direct relation to the duration of adolescence. The more the period of adolescence is extended, the more that of maturity is increased. All the education and instruction given to children is in violent contradiction to this law. All our efforts tend to the most rapid advancement toward physical and intellectual maturity.

As we enter the contemporary field of experimental science we need not be surprised that real data bearing upon the problems of longevity are almost as scarce as they were in the time of Aristotle or Roger Bacon.

In 1917 Osborne and Mendel[1] reported an experiment in which they attempted to prolong the lives of rats by retarding the growth. They found the reproductive activities of these rats extended to a greater age in the females, but unfortunately their rats died of disease before they determined the effect of retarded growth upon the life span. In 1917 Northrup[2] presented data with fruit-flies showing the entire life cycle was extended if you increased the larval period by inadequate feeding. The entomologist has long been aware that the total life cycle is prolonged by slowing down one of the stages of development.

In 1928 Raymond Pearl[3] in his book on "The Rate of Living" showed the significant negative correlation between the rate of growth and duration of life of cantaloup seedlings.

In our laboratory in 1927 an experiment was designed to study the relationship between the protein level in the diet of brook trout and the deficiency of an accessory factor we term "H" (to differentiate it from the vitamins required by higher animals). The diets for the series of groups of brook trout were all deficient in this essential vitamin, factor H. Therefore in the course of six months or less every trout was doomed to die. In addition to this vitamin deficiency, which was common in all diets, the amount of protein in the various diets was varied. One group received 10 per cent. protein, another 25 per cent., another 50 per cent. and a fourth 75 per cent. To secure growth, a diet for brook trout must contain about 14 per cent. protein. In this experiment all groups grew at about the same rate, except those upon the low level of protein. They failed to grow, but kept alive. However, the trout that grew died in about twelve weeks. Those that failed to grow upon this low protein level lived twice as long as those that grew. Thus it was postulated by us in 1928 that *something was consumed in growth that is essential for the maintenance of life*. At a later date this experiment was repeated and again it was found that trout that grew lived about half as long as those that were retarded in growth if both were kept upon a deficient diet.

While considering these studies with fish it may be well to review briefly the difference between the growth rates of fish and those of higher, warm-blooded animals.[4] If a young elephant in a zoo gained a pound in a day no one would be excited, but if the mouse that steals the elephant's food were to gain a pound a day it would be news. Therefore in considering the growth rate of any animal it must always be considered in terms of the body weight of the individual. Thus it can be stated better that the mouse and the elephant gain a given per cent. of their respective body weights

[1] T. B. Osborne, L. B. Mendel and E. L. Ferry, *Science*, 45: 294, 1917.

[2] J. Northrup, *Jour. Biol. Chem.*, 32: 123, 1917.

[3] R. Pearl, "The Rate of Living," Chap. 7, 1928.

[4] C. M. McCay, *Science*, 77: 411, 1933.

FEMALE RATS AT THE AGE OF TWO YEARS AND EIGHT MONTHS

THOSE ABOVE BELONGED TO GROUP 1 WHICH GREW TO MATURITY RAPIDLY. THE PHYSIOLOGICALLY YOUNG ONES BELOW ARE THE SAME AGE BUT THEY WERE RETARDED IN GROWTH AND MATURED LATE.

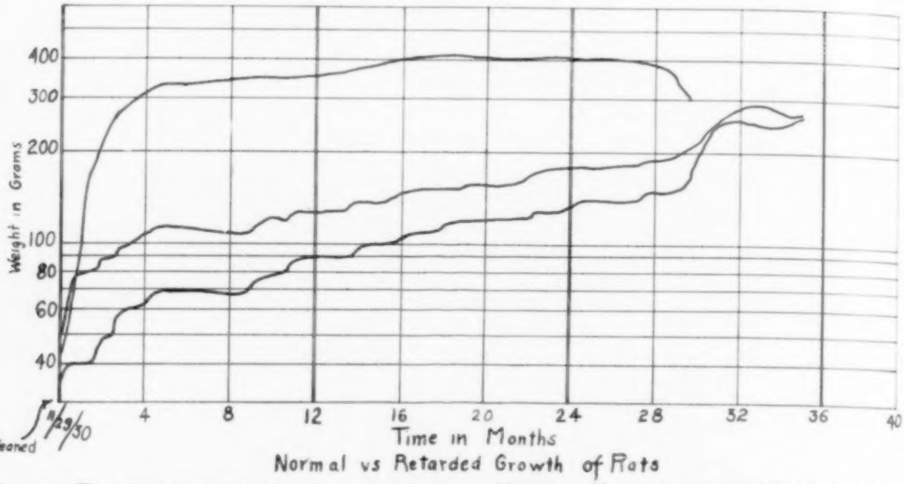

CHART. THE TOP CURVE SHOWS THE GROWTH OF A "NORMAL" ANIMAL FROM GROUP 1. THE TWO LOWER CURVES ARE TYPICAL FOR ANIMALS RETARDED IN GROWTH.

in a unit of time such as a day or month. In practise we determine such relationships automatically by plotting growth curves upon semi-logarithmic graph paper. Most higher animals from their early life in the uterus grow at a constantly decreasing rate. The baby tends to grow more rapidly than the boy of sixteen. This is not so with fish such as brook trout. In a given year during the growing season they maintain a constant growth rate. In other words, in each month the brook trout increases its weight by a constant per cent. of the body weight at the beginning of the month. If the entire life span of a brook trout is considered, however, it is found that the growth curve remains logarithmic during successive years. This curve is much steeper during the "fry" stage and during that of embryonic growth than it is during the second and third years of life. Thus the trout really decreases its growth rate as it ages and does not afford an exception to the findings of Minot that warm-blooded animals decrease their growth rates as they become older. Not only is this growth rate logarithmic but it is much slower than that for a pig or a chicken. No one has published growth curves of warm-water fish for comparison, however. Not much is known about the life span of fish, but it is well recognized that they are long lived. There is a record of a carp that lived 367 years, of a pike that lived 267 years. The authenticity of these records may be questioned, but it can be accepted that fish have long life spans.

As the discovery that trout live longer when they fail to grow is reviewed, the old law which Buffon (1707–1788) seems to have taken from Aristotle is worth recalling. Buffon claimed that the time required for an animal to grow to maturity could be multiplied by 6 or 7, and the resulting value would equal the life span. This law was discussed at intervals in the course of the eighteenth and nineteenth centuries. To-day it seems pretty well forgotten by the biologists. This law is interesting because it states that the life span is directly proportional to the growing period of a young animal. This law was devised from a consideration of the growth rates of various species such as

man, camel, horse, cow and dog. It was not based upon data concerning individuals within a given species. This law is interesting because it suggests a possible method of extending the life span of an individual. It also makes one aware of the many animals of widely different life spans that are available for experiments. Thus man is fortunate in having a much greater span of life than mice, rats, guinea pigs, chickens, rabbits, cockroaches and dogs. Within our reach is the possibility of determining the factors that set this limit to the life span or possibly to discover that the fixed life span is fictitious.

In order to test the assumption that an individual within a species that grows to maturity slowly will have a greater life span than one that grows rapidly, an experiment with white rats was designed. This species was selected because (1) its nutritional requirements are better defined than those of any other species. This has been the chief animal used in the laboratories for the past twenty years. (2) The white rat's span of life is about two years, normally. Therefore, an experiment would not need to extend over a period of more than five years. (3) The white rat is small enough so that large groups can be employed. Thus we can compensate for individuals that develop specific diseases that are not related to the experiment. (4) Numerous earlier studies had shown the white rat can be retarded in growth and still attain maturity. No marked stunting effect results from retarding the growth at least as far as any one has extended such retardation. (5) The white rat is similar to man in its nutrition and in the life spans of the opposite sexes. The female rat lives longer than the male. This is also true for the human species.

In planning the diet for this experiment it was desired to satisfy the nutritional requirements of the body in every respect, except that the body would have insufficient calories to permit growth when the food intake was restricted. We designed a diet that was adequate in vitamins, protein, inorganic salts and fats, even when the animal was restricted to a low level of intake each day. Thus for long periods the animals whose growth was retarded could be prevented from growing. At the same time the food ingested each day provided every recognized constituent to insure the health of the animal but not enough calories to permit growth. In such a case the real cause of the retardation of growth is probably due to the use of the protein for energy, since insufficient calories are allowed. Thus in final analysis the retardation may be due to protein in spite of a high level in the diet fed. This is analogous to an automobile in which the engine contains ample oil, the differential is well greased, the battery gives a good spark but only enough gas flows into the carburetor to permit the car to run 20 miles an hour. To make it run faster we feed the engine more calories. Likewise with the rat, the diet was adequate in every known respect. It was designed so that all that was needed to make the rat grow or to increase from its uniform rate was to feed it more calories. Sugar provides calories for the rat just as gasoline does for the automobile. No one expects "longevity" in an automobile without oil, grease and a few repair parts in addition to fuel. Likewise in the body of an animal we must have protein, inorganic material, vitamins and some fat. With these needs satisfied it was possible to control the rate of growth of the animals by calories alone.

In planning an experiment in which the growth of a young animal is retarded, it seems desirable to start as early as possible. In the case of the nursing young it is difficult to decrease the growth rate very much and still

TABLE I

LIFE SPANS OF RATS THAT MATURE SLOWLY COMPARED WITH THOSE MATURING RAPIDLY

Diet	Mean Life Span (Days) ♂	Mean Life Span (Days) ♀	Median Life Span (Days) ♂	Median Life Span (Days) ♀
I—Adequate calories (rapid growth)	509	801	522	820
II—Deficient calories (slow growth)*	(792)	(755)	797	904
III—Deficient calories (slow growth)*	(883)	(824)	919	894
Stock Diet (75) (rapid growth)†	503 ± 12		*Note:* Campbell discards early deaths while our data include them.	
Campbell‡ (A) (rapid growth)	576 ± 10	604		
Campbell‡ (B) (rapid growth)	635 ± 12.9	664		

* Values in parenthesis are still increasing, since the animals are alive.
† From unpublished data obtained from our rat colony five years ago.
‡ H. Louise Campbell, Thesis, Columbia University (1929).

keep the young alive and healthy. Furthermore, there is a transition period in which the animal is weaned and changed from milk to solid food. Retarding the growth during this period is also somewhat dangerous, since most species are very sensitive to changes during this time. In view of the difficulties in animal life immediately after weaning this experiment with rats was planned so that three groups were employed.

At the time of weaning 106 rats were divided into three groups, one containing 34 individuals and the other two 36 each. The members of one group were allowed to grow normally for two weeks they matured rapidly. The members of the second group were forced to grow very slowly by limiting their daily allowance of food from the time of weaning. The third group of rats was allowed to grow normally for two weeks after weaning. They were then restricted in their food allowance and forced to mature slowly. This restriction, providing all the necessary elements as we have stated, limited only the calories.

In the accompanying growth curves, the chart, we have selected curves for typical rats from each of the groups, and thus the course of growth is shown graphically. In rearing the retarded growth groups the practise has been followed of keeping them at a stationary weight for one to four months. A weight increase of about ten grams was then obtained by increasing the allowance of food. Part of these increases were made by feeding sugar only in addition to the regular allowance of food. At other times the step upward in the growth was induced by such rich sources of vitamins as beef liver. In each case the controls were also allowed the same additional and special foodstuffs, as the retarded growth groups during the same period of time.

In the accompanying chart the slow climb to maturity of the lucky rats or victims (as your philosophy dictates) can be seen. After more than 28 months all were allowed to mature. For the remainder of their lives they were allowed all the food they desired. Thirteen of these original rats were still alive after 1,200 days. All these were rats whose growth was retarded. This represents 18 per cent. of those from retarded growth groups and none of the rapidly maturing.

TABLE II

Number of Each Sex of Rats Alive at the Beginning and After 1,200 Days, Showing the Increased Life Span After Retarded Growth

Diet	No. animals start			No. animals alive at 1,200 days		
	♂	♀	Total	♂	♀	Total
I—Adequate calories (rapid growth)	14	22	36	0	0	0
II—Deficient calories (slow growth)	13	23	36	3	5	8
III—Deficient calories (slow growth)	15	19	34	2	3	5
Total alive			106			13

In Table I is a summary of the mean and median life spans which was made at 1,191 days. From groups I, II and III the only fixed value at 1,191 days was that for animals of diet I. Late in the first year of this experiment some of the females of the retarded growth groups were lost during the hot summer of 1931. This tends to distort the data for the mean life span of the females. For this reason the data for the median, which is a truer picture in this case, are included.

These data as well as those of Dr. Campbell of Columbia, which we have inserted for comparison, show that the life span of the female rat which matures rapidly is longer than that of the male. It is worth noting that the mean life span of the female rat in our experiments, even with rapid growth, was about a fifth longer than that found at Columbia. One can think of several explanations for this difference, such as diet or heredity. Another difference is that Dr. Campbell's rats were bred and bore young regularly, while those in our experiments were not allowed to reproduce. In this table are also inserted the results of an earlier experiment in which 75 male rats were kept in our colony until the end of their lives. Their mean life span was 503 days, while in the present case the value was 509 days. In these cases the diets and the years in which the experiments were run were quite different, but the growth rates and the life spans were similar. This affords additional evidence that the rate of growth and the life span are related if the diet is complete qualitatively.

The data are clear in regard to the male rat. They are less clear in regard to the female, since there are animals alive in each group except one. Furthermore, this table was made at a time well outside the period of the normal life span of our male rats but just outside the span for the female animals. Since even female rats that matured rapidly lived about a fifth longer than those of Miss Campbell, there is the possibility that growth of young within the uterus may remove some essential from the body of the mother and thus shorten her life span.

In Table II is a summary of the number of each sex at the beginning and at the end of 1,200 days, slightly more than three years. At the present time this experiment has been running 1,200 days and there are 13 animals alive. Since the average male rat lives from 500 to 600 days and the average man lives from 50 to 60 years, ten days in the life of a male rat is equivalent roughly to a year in that of a man.

Most of the rats that are alive now are more or less blind and some have been so for about half of the period. Thus it

seems that the eye fails before other parts of the body. These old animals, like old men, seem to be susceptible to lung infections and these seem to be the immediate cause of some deaths. The hair of the animals retarded in growth remained fine and silky for many months after that of the rapidly growing animals had become coarse. In studies with animals it is customary to observe the hair, since its condition frequently reveals changes that are taking place within the animal body.

In summarizing, these data indicate:

(1) That the life span of the rat is extended if the growth of the animal is retarded by inadequate calories and if an adequate intake of other essential nutrients is insured.

(2) That the potential life span of an animal species is unknown and greater than we have believed.

(3) That the difference in growth rates of the opposite sexes within a species may account for the differences in life span.

(4) That the problems of longevity can be attacked profitably to-day by means available in most nutrition laboratories.

Finally, in order that we may not become over-enthusiastic concerning the worth of longevity studies, it may be worth recalling the well-known lines of Lucretius with which he closes Book III of the "Nature of Things."

> Verily, a sure end of life is ordained for mortals, nor can we avoid death, but we must meet it. Moreover, we spend our time amid the same things, nor by length of life is any new pleasure hammered out. But so long as we have not what we crave, it seems to surpass all else; afterward, when that is ours, we crave something else, and the same thirst for life besets us ever, openmouthed. It is uncertain too what fortune, time to come, may carry to us, or what chance may bring us or what issue is at hand. Nor in truth by prolonging life do we take away a jot from the time of death, nor can we subtract anything whereby we may be perchance less long dead. Therefore you may live on to close as many generations as you will: yet no whit the less that everlasting death will await you, nor will he for a less long time be no more, who has made an end of life with to-day's light.

THE NEW POINT OF VIEW IN CHEMISTRY

By Dr. HENRY EYRING

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MAN'S interest in the physical world stretches from the farthest nebula to the nucleus of the atom. It is convenient to think of the world as being divided into parts on the basis of the measuring scale required in discussing it. Thus for the nebulae we think in terms of billions of light years. When we remember that light travels to the earth from the sun in about eight minutes we get some idea of how far it would travel in a year—the light year. Billions of light years is indeed a grand scale. The nebulae form an intensely interesting world, about which, however, relatively little is known. Much closer to us is the celestial world known to the ancients. The convenient scale for the planetary system is the actual distance in miles, and even for the stars we seldom require a scale larger than thousands of light years. This is the part of the world in which the laws of attraction and the mechanics which govern these bodies have been known for nearly three centuries. Indeed, if we will, we may know the time of an eclipse to the fraction of a second.

We next consider the world of everyday experience. In it we find the problems which send us searching into the world of x-ray dimensions, where lie the hidden causes of the properties of matter. To understand chemistry we must in fact master the forces which act between atoms when they are a hundred millionth of an inch apart. Here the last few years have brought revolutionary changes.

The analogous laws which began an epoch for celestial mechanics about three centuries ago have just been discovered in this fascinating chemical world. We now know that the forces between atoms arise entirely from the charges carried by the nuclei and electrons. This parallels the law of gravitational attraction for celestial bodies. Paralleling the Newtonian laws of motion we have the no less precise quantum mechanical laws of motion, together with the Pauli principle.

We pause to mention the last and smallest in these realms of human interest, the subatomic. Here the measuring rod is a million-millionth of an inch and the forces are gigantic. Here also the correct mechanics remains to be discovered and even the nature of the forces are shrouded in mystery. We may be sure, however, that this too is a mystery which human ingenuity will unveil, only to uncover newer mysteries beyond.

We now inquire what is the nature of this mechanics, which is transforming chemistry from a world in which every property of matter was of necessity empirical to one in which any property can be calculated—to be sure, at the price of enormous labor—but nevertheless it can be calculated. Since all the forces between the atoms arise from the fact that they are electrical charges, it is not surprising that when we can specify accurately the average relative position of these charges we can immediately calculate all their properties. The eigenfunction is the name given to the quantity whose square describes in detail the haunts of these particles, and the Pauli principle simply says that no two of these particles can simultaneously occupy the same haunts. This seems to be simply a highly sensible bit of atomic regulation to prevent overcrowding. Now the other important principle in quantum mechanics tells us how, by a slight but absolutely definite change, we obtain an operator from the Newtonian expression for a property which acts

upon an eigenfunction to yield the corresponding value of this property in our new mechanics.

This broad outline has been given simply to emphasize the fact that we now have this new mechanics which is a perfectly definite concrete system which all of us may, and those of us who are chemists must, if possible, learn to apply.

One naturally wonders, first, if there really is a correspondence with reality of this set of abstract operations and, even if there is, how the correspondence arose. In answering this, we should remind ourselves that the process of thought is itself experimental. When we start thinking about something strangely new, many of our ventures lead nowhere, but, if we try often enough, we finally build a logical system which is a faithful mirror of reality. If this system is well built, continuing the structure reveals a part of the physical world beyond previous experience. It is not strange, then, but certain that, if brilliant men think long enough about a rich world of experience, such as spectroscopy was during the first quarter of this century, a great logical method will arise which may be used to penetrate deeper into our unknown world.

What are some of the questions which we are called upon to unravel? The first is the great realm in which nothing changes with time. A typical question follows. Suppose there is oxygen in a vessel at a certain temperature and pressure, what fraction of the oxygen will be present as atoms and what part will be present in the form of oxygen molecules, each containing two atoms. This is a question extremely difficult to answer experimentally, to temperatures higher than about 1000° C., even approximately. With the help of spectroscopy and quantum mechanics precise values have been given up to about 6000° with comparative ease. This is a phase of the great chemical revolution of which very many equally striking examples could be cited, but instead we turn to an even more interesting question. How fast do chemical changes take place in the world? Life itself is but one phase of this fascinating question.

For molecules to combine to form new ones they must collide with catastrophic violence. The atoms in the two colliding molecules must approach so closely that they no longer know whether they are bound to the new or the old atoms. For convenience, this is known as the activated state. If these violent encounters occur once in every million million collisions, the reaction goes moderately fast. If they go once in every thousand million collisions an experimental chemist will be unable to distinguish between this and reaction on every collision. He will simply say in either case that the reaction goes immeasurably fast. By cooling his vessel he slows down all the molecules and can so cut down his rate to something measurable. Thus, simply by observing how a chemical reaction changes with temperature, he can tell you how violent a collision must be in a particular case to cause reaction; but, until the last three or four years, he could not even guess how violent a new type of collision must be to bring about a reaction. This the quantum mechanics has completely changed. He can now calculate, as accurately as he pleases, how energetic a collision must be to cause chemical change and, therefore, at what temperature it has a measurable rate. Moreover, approximate calculations, which are simply made, frequently tell him which of two reactions will go the faster. This is a type of question which to answer experimentally frequently requires a great amount of time and great expenditures of money.

For the exact calculations one needs no other data than the laws of quantum mechanics and the fact that one is dealing with a certain set of charged particles, and all the physical and chemical properties would emerge as a matter of

course. For the approximate calculations one derives an algebra which expresses the energy of complicated systems of atoms and molecules in terms of the energy which would bind the individual pairs if, in each case, the other atoms were not present. The binding energy for any pair is generally obtainable by well-known means from the lines of the spectra of the pair.

What particular types of questions may be answered in this way? Frequently it is observed that molecules which react together slowly, if at all, when left to themselves become enormously reactive in the presence of a certain solid surface, while others are speeded up by means of minute traces of certain enzymes also acting as catalysts. We first inquire why a particular substance is catalytically active, and secondly, what are the properties which a new substance must fulfil to serve equally well. Such calculations show that only atoms on a catalyst with the spacing proper for the particular reacting molecules will have the maximum effectiveness. It also gives just what this spacing should be in particular cases. Further, we find that the particular effectiveness of metals arises from the additive nature of the metal bonds. This is the very property which makes them form the characteristic metallic structure in which every atom is strongly bound to many neighbors. One need only remember that the possibility of the synthesis of ammonia by these same catalytic methods made possible the late war to appreciate in what a fundamental way such processes affect us all.

These same methods serve to calculate simply and easily how closely two molecules will approach in an ordinary collision, thus defining what has always been thought of as the size of the molecules. Another interesting phenomenon long known to chemists arises when an atom in a molecule is replaced by a large group which gets in the way of an oncoming molecule during a collision that would otherwise result in reaction. This makes it necessary for the reaction to be more violent by an amount which agrees with the calculated values in an interesting way. There are of course many such examples that could be cited, but we turn now to the interesting field of isotopes.

Soddy originally defined two isotopes as two molecules having identical chemical properties but different atomic weights. Perhaps heavy hydrogen or deuterium, discovered by Urey, Brickwedde and Murphy, has shown its iconoclasm in no more striking manner than in the absolute scorn it shows for this interesting definition. In fact, Professor Soddy has even suggested that rather than amend the definition it seemed wiser to discard the idea that deuterium is an isotope of hydrogen and instead regard it as a new element. Such a proposal of course does not remove the difficulty, since in fact any two isotopes differ in chemical properties by an amount roughly proportional to their masses, so that for the heavier atoms the results only become smaller but never disappear.

The whole theory of the separation of isotopes and the difference in chemical reactivity arise from a difference in the bond strengths for the two isotopes. This in turn arises from the so-called "different zero point energies," which we may explain in the following way. Because the deuterium and hydrogen atoms each have a single negatively charged electron with a nucleus carrying a single positive charge a pair of atoms of either kind exert almost exactly the same forces on each other at the same distances. However, the quantum mechanics tells us that such a pair of atoms has the peculiar property of retaining a definite amount of vibrational energy, even at the absolute zero of temperature. This amount being proportional to the frequency of vibration and with the

same forces pulling on them, it is clear that the lighter ones will vibrate more rapidly. The result of this is of course that because the light hydrogen has the most energy to start with less will be required to break it up into atoms or to shatter it enough to permit it to react with any other molecule.

Such considerations show that if you had a solution containing one half ordinary water and the other half heavy water then, in the gas phase above the molecules, there will be very few ions of either kind, but there will be twelve times as many hydrogen as deuterium ions. Since the lighter hydrogen ions also move 40 per cent. faster than the deuterium ions, you would find, if there were a tiny hole in your apparatus which would only allow ions to pass, that 18 times as many light as heavy hydrogen ions would emerge. This of course would give a very excellent separation of the two kinds of water but unfortunately at a very slow rate. However, this slowness is remedied by passing an electric current through the water and so forcing the ions to leave the solution and allowing them then to combine to give hydrogen and deuterium on the metal electrodes. If the electrodes are made of platinum the separation factor, instead of being 18, as in the ideal case, is only 8. If the electrodes are made of mercury this factor is 2.8. Iron and nickel give values of 7 and 5.5, respectively. The differences from the ideal separation factor, although fairly well understood, are of no particular interest to us now. The interesting point is that you get separation of light and heavy water no matter what metal you use for your electrode or what substance you dissolve in your water, and the only reason some one did not find it a hundred years ago is because they did not try. They did not try earlier because they did not understand spectroscopy sufficiently well to identify the spectral lines; but, most of all, they did not know the quantum mechanics which would allow them to know exactly the position of the old lines of hydrogen nor the possible new faint ones for deuterium.

From what has been said it must be clear that, in general, hydrogen will react from 3 to 18 times faster than deuterium if the process involves breaking a hydrogen or deuterium bond. Deuterium may react slightly faster in the rare cases in which the reactants are the free atoms.

What value will deuterium have in the study of reactions? If, in a reaction, the slow process involves breaking a hydrogen bond, then when we replace a hydrogen by deuterium the reaction will be found to go much more slowly. Conversely, if we find a deuterium compound reacts more slowly than the corresponding hydrogen compound the rate-determining step in the reaction must involve the breaking of a hydrogen or deuterium bond.

The field of biochemical reactions is of course a complicated one, but we are at least safe in saying that all the considerations mentioned above should be valid for such cases also. Often of secondary importance are the different physical properties of deuterium water, such as lower dielectric constant and lower solubility of dissolved compounds, greater density, boiling point, freezing point, and so on, although they are by no means negligible. There are of course a very great number of interesting examples illustrating these effects already known. We shall mention here but two. Various people, including Lewis, have shown that compounds of hydrogen not ordinarily thought of as acids still have the property of having their hydrogen atoms replaced by deuterium when dissolved in heavy water. This of course should remind us that even though compounds do not have hydrogen atoms so loosely bound that they act like acids they may still be loose enough that they can react once in every thousand million

collisions and so have the appearance of going instantaneously.

Another startling result of Taylor and Pace is that both hydrogen and deuterium are taken up by solid chromium oxide equally rapidly. The specialists in the field of catalysis, particularly Taylor, have always assumed that the slow process in the activation of the hydrogen at surfaces involved the breaking of hydrogen or deuterium bonds, but this seems to indicate that the slow process involves some preliminary rearrangement in the chromium oxide itself, which is a rather startling result. More cases must be studied before we can feel certain of such an interpretation. This should, however, give one a feeling for the kind of fundamentally interesting problems which this new isotope prepares us to attack.

It is perhaps of some interest to indicate the expense attached to the manufacture of heavy water. At Princeton at the present time there is produced 3 cc a day at a cost of about $5 to $8 a cc to be compared with earlier estimated costs of a number of people of $80 and more per cc. The method of procedure is very simple and has in fact been described elsewhere.

Perhaps the most striking of the very recent work on isotopes is the discovery of hydrogen of mass three. Rutherford and his coworkers, bombarding NH_4Cl with deuterium, discovered that atoms of tritium, hydrogen of mass three, were formed. Gould and Bleakney at Princeton, using some of the 98 per cent. heavy water in a mass spectrograph, found that tritium is not present in ordinary water in quantities as large as one part in a hundred million. In the meantime, Bleakney and his coworkers developed a much more sensitive mass spectrograph and found that tritium does exist in ordinary water to the extent of two parts in a billion. Curiously enough, this is just barely outside the range of the earlier instrument used.

Quite recently, Professor Harnwell and coworkers at Princeton shot deuterium molecule ions at high velocities into other deuterium molecules and increased the amount of tritium by several fold.

It is easy to summarize the general properties of this new kind of very heavy water. In the first place, it would cost a million dollars a cc to prepare it if one used the same methods applied successfully to deuterium. To obtain one cc of this water one would have to electrolyze away the water in a pool a foot deep and 200 feet square. Tritium heavy water is 20 per cent. heavier than ordinary water, as compared with 10 per cent. for D_2O. The chemical reactions of tritium will be still more sluggish than those of deuterium. Under circumstances in which the latter reacts a fifth as fast as ordinary water the former will react a tenth as fast. There will be in fact little or no difficulty in predicting all the properties of tritium from the quantum theory and from a knowledge of deuterium. The prediction depends principally upon the zero point energies involved. Interestingly enough Polanyi and Eyring, using quantum mechanics to predict rates of chemical reactions, outlined the effects of zero point energy on reaction rates some time before the heavy isotopes were discovered in whose reactions zero point energy plays such an important rôle.

It has been my purpose to point out that the same rapid developments which followed the discovery of the laws of force and the mechanics of heavenly bodies almost three centuries ago are now beginning in chemistry and that we must expect a large part of chemistry to become rapidly transformed into a much more exact science. Individuals or universities who do not take account of the trends of the times and who fail to direct their efforts to meeting such changes are doomed to fall far short of their utmost possibilities.

MATHEMATICS—THE SUBTLE FINE ART

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I. Introduction

Mathematicians are often confronted with the question: "What is mathematics?" And a second follows in its train: "Why should mathematics be of interest to any but the few." Many definitions of mathematics have been given, but upon examination they have all turned out to be inadequate. A good many thinkers have given answers to the second question, but they have never been very convincing. It has been urged that mathematics is useful. So it is, and to many its sole reason for being is the same as that of the kitchen scullion. Some one must do the drudgery. It has been urged that mathematics is the most powerful aid to logical or correct thinking. And it is true that mathematics seems at least to be correct. And mathematics never loses its creations. One can take considerable pleasure in the fact that one of my students expressed himself thus: "I am heartily thankful there is one subject in my curriculum that remains the same to-day as yesterday." When one thinks about it he sees that in all the range of human thought, but one subject has steadily added to its riches, and never has thrown away anything—mathematics. Science denies this decade what it taught last decade. History is questioned on every side. The sciences of humanity are ever remade. With the exception of mathematics all knowledge is subject to revision. This is an excellent reason for becoming acquainted with it, but it is not a necessary reason. For we meet a new question: Is mathematics knowledge, and if so, knowledge of what? This reduces the second question to the first, and we must consider it before we can consider the other. What is mathematics?

In order to arrive at an answer we must go back, as Descartes did, to the human consciousness itself. What do we find in the conscious life of man as the dominant essences of that life? One is the ability to hoard the conscious life, to capture some of the wild birds that flit past our present. Another is the ability to wave a magic wand like Prospero and bring into being birds and butterflies, Ariel and all the trains of fairies, castles and storied towers, music and poetry. Man is a dreamer, but some of his dreams he can capture and keep.

These two characters have been evident at all times in the long stretch of the human race from the dawn of history to the present. Man has never accepted the world around him as do the animals. He has always undertaken to change it and make it into something different. He makes water run uphill; he piles up stone or steel even to the clouds; he tames the wild beast and puts him to work; he talks 'round the world; he protects himself so that he lives in the tropics or at the poles. Sometimes he is whirled about in the winds of nature, but he does not accept this fate. He remembers what he has done in the past and wherein he failed, and on the basis of these memories, which he calls knowledge, he conceives visions of what he can do in the future. He is constantly endeavoring to let loose an innate power, a desire for activity. It is not necessarily practical work he is doing, for just as often it is the exercise of the play desires he possesses. He often undertakes projects that have no particularly practical end. The dance for the green corn is to cause good crops, but it is also the outlet of spiritual

power. What practical end does "The Tempest" serve? The modern slender spire that rises up in the heart of a swarming city is practical, perhaps, but it is far more the satisfying success of an artist to realize a dream. Man knows that he is not a mere spectator in the universe of phenomena, seeing things only by "flashes of lightning, all the rest darkness." Neither is he a walking doll, that says "mamma," then goes to the ashbarrel when broken. He is an adventurer, often undertaking the impossible, and making it possible. He is the living volcano of flame and dust which must release its power.

But his life is not simply the exhibition of activity. There is inside him, not always consciously, a longing which haunts him, a longing for an invisible, intangible, inaudible reality called beauty. This he finds is just as insistent as the desire for comfort. He must build a habitation for shelter, but he does more than this, for he builds it in such a way as to satisfy this desire for an elusive thing which later he calls beauty. In time this indeed comes to be more important than anything else, for he sees that this reality indeed is himself. It is a glorified expression of that which he sees himself potentially to be. Whatever means he may make use of will be as inadequate as are paper and ink to carry the impassioned lover's rhapsody. When the first primitive tribe with sweating labor managed to stand on end a huge monolith, their expression of the majesty and power of their first vague intuition of the Unknown, their own dim consciousness of capabilities, of powers to be attained only in the tedious march of centuries, reaching up higher than they, solid and undisturbed by rain or frost, was there nothing real and permanent for which this clumsy symbol stood? Even the archeologists and ethnologists who see in it nothing but a phallic symbol have to admit that the insurgency of life and the urge to creation are worth a symbol which shows them as eternal realities.

The twofold character of the psyche is easily evident with only a small amount of reflection and very little insight. There is the ability to crystallize the evanescent and flowing waves of events into definite and stable forms, and this is called knowledge. Then there is the constant urge to create new elements, more spontaneity, unguessed and undreamed forms of the inner life, and this is called art. So fleeting is the configuration of the psyche that the fixed and stable elements are ascribed not to it but to an objective world which is assumed to be independent of the psyche. Knowledge is assumed to be an understanding of an extraneous entity. Art is assumed to be mere play of the spirit, fleeting emotion, of only passing interest. Both assumptions are incorrect, since knowledge is the more or less temporary system of invariants the psyche plays with, while art is the emergence of the new life-forms of the psyche itself. Those creations of the psyche which it retains for awhile constitute knowledge, and the creating of a new form is art. It is easy to restate knowledge, since its forms are for awhile permanent, but to state art one must accompany the wild duck in its flight, must freeze the rainbow the sun produces against the shower of events. This means of course that knowledge and art are human, even though they plumb the absolute. What sort of psychical material a Martian cherishes as knowledge we can not know. What sort of art he creates we can not know either.

The stable routes from one item of knowledge to another we call logic. They seem to us to be necessary, but merely because we have made them habitual in going from one judgment to another. To find other routes would be an act of creation, which would be art,

not logic, and this process of making new logic is actually going on. Stable modes of art would be impossible, since creation implies the unexpected, the versatile, the ever-new. This does not mean that in the creative process there is not a permanent reality. Reality does not mean fixity, crystalline structure. Any organism that maintains its individuality as an organism, even though subject to a steady flux of material, even though every atom, material or mental, is changing momentarily into a new atom, is still a reality. The human body is a reality, the immaterial sieve through which chemicals flow. The reality of art has this nature. An easy example is dual symmetry, the complementary phases together constituting the unitary symmetry. This may be in positive and negative number, geometric reflection in a plane mirror, in sine and cosine, in wave and particle, in the façade of a temple, in the right and left of the human form, in the purple and yellow of the sunset, in the assonance and dissonance in music, in the earthly and the heavenly love, in male and female, in good and evil—what matter the medium in which the dual symmetry express itself? The reality is that which generates the symmetry, the forms are adventitious. The stable idea of symmetry is knowledge, the actualizing of symmetry in some form is art. Indeed, knowledge and art are phases of a dual symmetry in the psyche itself, though there may also be found trinities, quaternities and an unlimited variety of other forms. The struggle of the poise of the spirit with its medium of expression is often intense: "White, white blossom, fall of the shattered cups day on day."[1] To many of the realities of art there do not correspond ideas; they are not expressible in the abstractions and static forms of language. The nearest approach in language is in creative, metaphorical, suggestive poetry. Hence stating an example in words is very inadequate, it is at best only a sort of ticket for reality itself. "Art is the very flowering, the tangible flowering, of the creative soul come to ecstasy."[2]

There is a constant interplay of the two characters of the psyche. It is the creative character which furnishes knowledge its hypotheses, the most steady source of advance in science. It is the crystallizing character which furnishes art its types of expression, the most steady source of production of art works. Research goes on all the time both ways. On the knowledge side it usually consists in an increase in dispersive power so as to split principles into more universal principles or more fundamental hypotheses. On the art side it usually consists in experiments made to find a more adequate method of handling the medium, so as to express the artist's vision. Often the apparently unrelated researches are the same down in the depths of the psyche. It has been pointed out that much of modern art is an actualizing in art forms of the same universal invariants as appear in science in the Einstein theory. Human life, after all, is unitary, and we should expect this symmetric dualism in its manifestations. When the crystallizations made by the psyche no longer are useful and do not fit our evolving experience, we have an advance in science. It sweeps away what was called knowledge, and puts it into the museum of discarded theories. Where is to-day the ether which fifty years ago had a density, a rigidity, an elasticity, and was indeed a collection of very contradictory qualities? When the forms used by the artist no longer convey his message, have become lifeless and unsuggestive, we have an advance in art. The daring imagination of Wagner in music gave a new meaning to musical forms. The multitude usually does not welcome these ad-

[1] J. G. Fletcher, "White Symphony."

[2] J. Cheney, "The New World Architecture," p. 347.

vances, for the multitude likes what it is in the habit of having, it resists change, and society in general is conservative. No doubt the first savage to use fire for cooking was accused of impiety, of trying to upset society, of increasing the difficulty of living.

The aspirations of the spirit, however, produce new events in art, and the study of such aspirations is in the end more important than the study of phenomena in the world of nature. Every aspiration has something which may be clasped to the heart and in this way become knowledge, knowledge of life and what it means. When these aspirations which find expression in art forms become organized into living forms, they become visions. These visions have been the dominating forces in the life of man through all the ages, much more than his material environment. Knowledge enables us to secure ourselves against the play of material powers that would destroy us, the frost, the lightning, hunger, pain, illness. But spiritual visions enable us to wish to be secure so that we may expand into flowers that will not perish under the hurricanes and tempests of nature. For a few decades, the study of material phenomena has occupied man extensively, science has become quite powerful, and its success in giving us power to control the world of nature makes it a dominating force in life. But when it undertook to explain the life of art and the spirit, its words were ashes in the mouth, and to-day its finality has vanished.

In his "Dance of Life," Havelock Ellis says: ". . . where we reach the sphere of mathematics, we are among the processes which seem to some the most inhuman of all human activities and the most remote from poetry. Yet it is here that the artist has the fullest scope for his imagination. . . . We are in the imaginative sphere of art, and the mathematician is engaged in a work of creation which resembles music in its orderliness, and is yet reproducing on another plane the order of the universe and so becoming as it were a music of the spheres. . . . The mathematician has reached the highest rung of the ladder of human thought. But it is always the same ladder which we have all of us been ascending, alike from the infancy of the individual, and the infancy of the race. Molière's Jourdain had been speaking prose for more than forty years without knowing it. Mankind has been thinking poetry throughout its long career and remained equally ignorant."

Many mathematicians have said that mathematics is art. Poincaré, Sylvester, Pringsheim, Kummer, Kronecker, Helmholtz, Bôcher, B. Peirce, Russell, Hobson, Picard, Hadamard, and many others, have felt and seen the qualities that beauty shows in the various parts of mathematics. And we may reverse the statement, and just as physics, which was an observational science, ultimately became "the theory of certain differential equations," and at present may be said to have become "the theory of certain linear operators," so art in every line, every phase, every mode of expression, has become the outward expression of certain forms of beauty, simply as sheer beauty. Pure art is as abstract as mathematics. No intention exists of representing nature or man, even in a glorified state. Debussy's nocturnes express sparkling flashes of spiritual insights, Picasso's diagrammatic paintings express designs of the spirit itself. Even if the attempt be futile, as John Gould Fletcher says, the artist must keep on:

> Like spraying rockets
> My peonies shower
> Their glories on the night.
> Towards the impossible,
> Towards the inaccessible,
> Towards the ultimate,
> Towards the silence,
> Towards the eternal,
> These blossoms go.

II. Mathematics

What any art undertakes to do is to give an expression to beauty. In the artist are living, evolving qualities which embody themselves in the art form. The art form once produced becomes part of human consciousness, and on the one hand incites the individual to become a creator himself, at least in a vicarious way, and on the other hand gives him something permanent which he can add to the stable organism he calls himself. At present we will pass over the first phase because we are interested in the second. As knowledge we examine the art form to discover what its structure is. For it has a definite structure, as has everything in the universe. Even if the art form is existent only as music, which passes away with the playing, or as the dance, which ceases when the dancer is still, there is involved in the whole event a definite structure. The static arts—architecture, painting, sculpture, poetry, mathematics—leave a permanent product which may be examined again and again, and the structure can be studied leisurely. But the dynamic arts are birds that must be studied on the wing. They are flowers whose petals expand with the seeing, and then they are gone. Even if they can be repeated, the new expression is never quite the same as the old. Yet they have a structure which is the same. The elements of structure as knowledge in beauty have been named: Rhythm, order, design, harmony. These appear in every art. In the distant future we may expect to find new elements of structure besides these. Of course to be an organism each work of art exhibits these elements as held together in unity. It must be sufficient unto itself. The "Unfinished Symphony" haunts us with wistfulness. In every case the artist brings into being a new creature for the world of spirit; he gives life to it; he watches it enter into his own being, and he may find that it helps him to interpret the riddle of the Sphinx. If we had time we could show that many new concepts of science have had an origin like this.

When we come to consider mathematics we may paraphrase Sandburg and say, "Mathematics is the achievement of the synthesis of hyacinths and biscuits." And we shall find the mathematician more interested in the hyacinths than in the biscuits. Mathematics is engaged in fact in the profound study of and the expression of beauty. The medium used is very ethereal, being pure ideas, nothing material, and this justifies the statement that mathematics is the subtle fine art. Its medium is sublimated to the very limit. It does not depend upon the perceptions of the senses, nor upon matter. No material experiment could have the slightest effect upon a mathematical theorem. The existence of its objects is not in the world of sight. Nature never makes a perfect circle, nor draws a straight line. No fractional numbers exist in her building material, nor is there such a thing as a negative. Kempe defined mathematics as the science of pure form, but this is a somewhat empty concept. C. S. Peirce defined it as the study of ideal constructions. But an ideal construction is a structure. And of what? And by ideal he did not mean abstract, ghostly, purely non-existent.

If now we examine the various parts of mathematics to see what they are essentially, we shall find that they are concerned with the study of these elements of beauty named above; perhaps with particular expressions of the elements, or in the most profound way with the very essence, the spirit of the element in any particular form. In each case there are two phases, one static, furnishing patterns for the element, the other dynamic, furnishing motricities for the element. A pattern is something that remains crystallized, a motricity is

something that parades its life before us. The White Knight said to Alice, "That is not the song, it is the name of the song." Nor is the printed verse the song. The song is gone with the singing. Yet the singing has a flowing pattern which is a motricity. So we have patterns and motricities of rhythm, patterns and motricities of order, patterns and motricities of design, patterns and motricities of harmony. These we find are what mathematics is concerned about.

III. Rhythm

Rhythm is an element of the structure of beauty. But modern physics says that rhythm is the fundamental element in the structure of the entire material universe. It swings around in great spirals the hosts of some island universe distant 300,000,000 light years; it wheels the members of a solar system in their ponderous orbits; it turns the hugest planet like a flywheel; it pulses in the flow of photons of light; it is the heart-beat of the atom; it is the only element of structure known for matter and energy. Wave-mechanics is a new term, but it has become the basic study for the physicist.

When the dawn of intelligence made Eoandros notice the world he was in, he must certainly have soon become aware of the pound, pound, pound, of his over-taxed heart when he had fled the saber-toothed tiger. He must have noticed the rhythm in the beat of the waves on the shore of the lake. He heard rhythm in the call of the crow. Day and night was a persistent rhythm. The flowing curves of birds in their flight, the arrangement of the leaves on the stem of the daisy, the way the petals of the primrose grew, almost all the items of his daily life surrounded him with rhythms. As he developed he began to hold on to certain of these rhythms, and these became knowledge, the knowledge of numbers—at first integers, one, two, three, four, five. In trying to follow the differences in phyllotaxis on a stem he would find fractions, two in five, three in eight. He was beginning the theory of numbers, even though he did not know it. Theory of numbers is still the many-threaded web of mathematics, and is far from being fully untangled. But in essence it is only the study of the structure of pure rhythms. Each prime number starts a new series of ripples, and the list of primes has no end. Do all these waves exist in nature? Apparently not. The imagination of man far outruns the needs of nature. Even the numerous waves of the terrestrial ninety-two atoms occur only in very definite series. These series are quite few compared to the endless list there may be. It was indeed a great source of satisfaction to the physicist when he found out that the series were few in number. His multitudinous chaos is overwhelming enough, even at that. And even when the waves run in packets and simulate particles, the wave-crests furnish only a few rhythms.

Centuries later in the history of man a majestic figure down by the Icarian Sea draws diagrams in the sand. They have all the mystic properties of rhythm: triangles, squares, pentagons, pentagrams, hexagons, figures inscribed inside of figures; then tetrahedra, cubes, dodekahedra, the ikosahedron—even the names are still Greek—all were full of rhythm, and they gave Pythagoras a vision far ahead of his time, a vision of the whole universe as built on rhythm. Number ruled everything, he was quite convinced. And he was more nearly right than was thought until recently. But one dreary day he and his school were appalled to find that there was no rational rhythm between the side of a square and its diagonal. Irrational numbers had emerged and they frightened their creators, and their magnificent temple of rhythm tumbled in ruins around the little band. Little they dreamed of the innumerable arrays of

irrational numbers yet to come, bringing intricate new rhythms. The years rolled on in their cycles, and then one day a rebellious youth named Évariste Galois looked more closely at the irrational roots of equations, and saw rhythm emerging again in beautiful new types. All algebraic irrationals come from certain normal equations, and each normal equation furnishes a flower whose petals are the roots, arranged in cycles and clusters of cycles, of two, three, four, five and so on. The simple flowers of Eoandros have expanded into complicated forms, but with very definite structure for their rhythms. The refractory quintic has been shown to depend on a normal equation of order sixty, but the sixty petals of this flower are arranged in fives, threes and twos, twelve fives, twenty threes, thirty twos, and the transition from one five to another is given by a dance pattern of great beauty. Hamilton playfully embodied it in his Icosian game, its first expression. Irrationals are a creation of the spirit of man, and show forth certain innate rhythms in his own spirit.

But rhythm is not confined to number. For we find that algebraic forms also have their rhythms, and the modular study of these—quite complicated in itself—consists in the finding of these rhythmic relations. An example is the field of symmetric expressions on N letters. Finite geometries also exhibit the same essence. Even in the study of linear differential equations we again discover systems of related functions much like the conjugate irrationals of Galois, for the Vessiot theory is just this in its study of the domain of functions which are roots of these differential equations.

More has emerged, too, than the static arrangements of frozen flowers. For Galois saw that the transitions from one of his sets to another were rhythmic also, and in the place of crystallized patterns we now have flowering motricities. He called them groups in connection with the roots of equations. And these groups, too, we find in a limited number in nature. If we examine the shapes of crystals, we find that they are solids with faces all alike, and the transition from one face to another gives a set of changes which make a group. For we arrive at all the faces from *any* particular one by the *same* set of changes, just as we can derive by the same rational expressions every root of a normal equation from any one. There are only thirty-two types of crystals, however, so the long list of groups is not very much used by nature. Groups of operators they are frequently called. We might set them on a stage and call them dance-patterns.

This opens to us also the meaning of the realm of geometry. It was Klein, in his address at Erlangen, who pointed out that every type of geometry was a listing of what did not change in the transition from one figure to another under given conditions. Projective geometry with all its beauty is one of these systems of rhythmic change. Inversion, geometry, conformal geometry, and other Cremona geometries are also examples. The bewildering arrays of forms begin to come into order and their relations are easily apparent.

But we have still more extensive riches in the motricities of rhythm, for we are now in the field of linear operators, with their fundamental functions. This gives us the power to handle wave-mechanics, and in fact wave-mechanics is in essence the study of the rhythms of the so-called ψ-functions of modern physics. But again what the mathematician studies is infinitely more than the physicist can use. The creative ability of the spirit of man finds its outlet in the creation of ideals. And in the process much knowledge which was considered valuable is swept away, for that which in modern times is worth saving in these outflowerings of the spirit is

more far-reaching in its usefulness, more condensed, more generalized, more suggestive.

IV. Order

Another element in the structure of beauty we call order. Order was early in its appearance to man. When he studied a square, he found that all the angles at the corners were alike. The diagonals had the same length. They crossed each other, making angles like those in the corners. Also, if he made squares on the three sides of a right triangle, that on the hypotenuse could be made exactly out of pieces of the smaller squares on the sides. Diagram after diagram was investigated, and the collection of theorems they found was put together by Euclid. Geometry it was called, for it could be used in surveying. But this practical side was scorned by the real artists. When a student who had learned a new theorem in Plato's Akadême asked what use he could make of it, the master called a slave and said: "Give him two-pence, since he must make money out of what he learns." They considered the various forms of order they discovered as sacred, and not for the common herd of human cattle. These subtle connections in figures became more and more elaborate as time passed. Perhaps we should end the Greek geometry with the investigation of Apollonius on the figure made by circles tangent to three given circles. When another young French genius, named Pascal, discovered the famous theorem bearing his name, he had an order which includes all the properties of conic sections. If we select any six points on an ellipse and number them in any way, 1, 2, 3, 4, 5, 6, then join 1,2 and 4,5 and find where the lines intersect, then 2,3 and 5,6, and find the intersection, and finally 3,4 and 6,1, and find the intersection, the three points of intersection will always line on a straight line called a Pascal line. Since the six points can be numbered in sixty different ways, there are sixty Pascal lines. These go by fours through forty-five points called Kirkman points, three on each Pascal line. The diagram becomes more and more complicated. And we could have used a circle or a parabola or a hyperbola or even two straight lines in a plane, instead of the ellipse, with like results.

There is order of course in any vision of an artist. If we put together tones we find both horizontal and vertical orders for them. We study this in counterpoint. If we examine an abstraction of Picasso's, the colored triangles, rods, violins and other forms have an order which is the real essence of the picture. Stravinsky's compositions might seem chaotic, but they have a subtle order. Any system of theorems about the products of art may be called the list of order patterns found.

Man reached beyond the world of sense again in this region, too. For the puzzling parallel axiom ultimately led Lobatchevsky to try to see where the contradiction would enter if he made a geometry in which this assumption was left out. The result was startling, for much to his surprise and delight, he created a new world. One non-Euclidean geometry had been born, and now there are many. It was found that psychologically we are built on the non-Euclidean plan, and the very simple constructions of Euclid were utterly nonexistent for our senses. Many painters unconsciously make use of this now in what looks like queer perspective and outlandish arrangements. However, they are giving visible form to ideas in order that express new visions of beauty. In music, the drama, the dance, we find it also. And even in poetry non-Euclidean arrangements seem to be necessary. Gertrude Stein has experimented with many.

We go further, however, for man is not contented with the order he gets from a two-way system or a three-way

system. He has created four-dimensional geometry, and even has dreamed of a universe for himself which is four-dimensional. He tries to put length, breadth, thickness and depth into one figure. At any rate, in architectural ornamentation Claude Bragdon has shown the beauty in traceries that depend on four-dimensional order. The relativity theory at first tried to coordinate space as we see it, and the flow through time as we feel it, and thus have a four-dimensional space-time world. In such a world every human life would be a complete, finished, predetermined, static thing. Our appearance in the world of others would be like the figure made on the surface of a pond, if we should gradually and smoothly draw up a solid object from the bottom of the pond. And if four dimensions, let us also have five, six, a million, an infinity.

Then, too, these order-relations do not have to be seen in space forms. We can find them in algebraic expressions as related to one another, and it was a brilliant day for the mathematical artist when Descartes said, "Geometry and algebra are one." Indeed, most geometry to-day is the study of algebraic expressions, in a geometric language. As an example of algebraic order, the product of sums of two squares is the sum of two squares, the product of sums of four squares is the sum of four squares, likewise for eight squares.

If we pass from the patterns we find for order, to the motricities, the flowing types of order, we also have inexhaustible riches. We call these "algebras." When Hamilton saw four worlds of rhythms, arranged in the quaternion algebra, the human spirit had been liberated into an entirely new universe. Equations could now have not only the flower-clusters of Galois as solutions, but each petal itself became a new world, and there were flower-clusters of universes. Every equation now has but one root, very complicated it is true, but unity has been restored to the theory. And unity is one of the essential elements of beauty. These hyper-algebras have been found in the last decade in the problems of physics, and indeed without hyper-algebras physics would not have solved its problems even in the partial manner they have been handled. In the simple case of complex numbers, Steinmetz pointed out that alternating theory could be brought into unity with direct theory in their laws, by considering that each current, electromotive force and impedance was really a single complex entity and not two independent entities. It is complex algebra that slides along a power line, or sings in the radio. And hyper-algebra vibrates in the levels of the spectral lines which come from Arcturus, Sirius or Antares.

The artist who combines music and mobile-color or music and the dance is a hyper-algebraist. Color and tone are two qualitatively distinct rhythms, as are tone and motion, neither can be turned into the other. To unify a composition which puts them together depends upon the synthetizing ability of the human spirit to make a unit out of the expression and is to work in hyper-algebraic relations. The modern synchronic arts try to do this difficult thing. If they fail occasionally, that means nothing. The problem is to succeed even once. Then, if we combine music, mobile-color, the dance and poetry, we have indeed a four-dimensional world to live in, and the possibilities of subtle art expression are unlimited. We get visions of beauty and of infinity and of eternity. Ruth St. Denis consciously, or unconsciously, has some such vision as her guiding star. In mathematical forms, however, each dimension may be turned into any other. And this is the complete triumph of this mode of art.

V. Design

Another element in the structure of beauty is design. This is the arrange-

ment of things, the way they are combined. The series of colors in the rainbow is a design. The stars of snowflakes are designs. The frost gardens on the window-pane are designs. We find a design made up of repeated elements which are alike, as the ripples that play over the surface of a lake, the many spirals of the pine cone, the call of the whip-poor-will. Or we may find a design in the fading terms of an arithmetic series. Design may be combined with rhythm, either periodic or cadenced. Or design may occur in a continuous series. The tangent lines of a circle constitute a design, the definition being that each is at the same fixed distance from the center. The Grand Canyon is a design, so is the Painted Desert, and so is the uranium atom. Clouds execute designs that may float across the sapphire sky, or they may wind like wraiths through the canyons of the mountains. Cloud shadows make designs across the slopes. And in Georgia O'Keefe's wonderful designs the flowing rhythms of wind, water, flame and mountains constitutes the picture. The label is of no importance. In the brilliant diagrams of Kandinsky color-design is the prominent feature. The statues of Archipenko are designs, not portraits, and in a large collection of mathematical models of surfaces, we may find statues much like those of Archipenko. When we divest our art form of the representative character, do not try to imitate objects, undertake in short to be abstract artists, then we can see design more easily. In the American Indian art we have come to appreciate this kind of design, often of high order. In sheer music we have abstract design perhaps for our day at its highest. Abstract art as it is to-day is an emphasis on design, whether it be in John G. Fletcher's poetry, in "Pelléas and Mélisande," in the marvelous dream of Eliel Saarinnen for a city building, in an abstraction of Duchamp-Villon, in Russell's Synchromie Cosmique, in a composition of mobile color, in the Fire-Bird of Stravinsky, or in an abstract dance—poetry and music in motion—in all these we find or should find design. In many branches of mathematics we are studying purely the structure of design.

If we consider the points of a circle we have a design of points, so for any locus of points. If we consider the tangents of an ellipse we have a design of lines, and so for any envelope. The description of the design may be very brief, as in the differential equation $ydx - xdy = 0$ we are merely saying: Draw all the straight lines in a plane that go through a fixed point, like the spokes of a wheel. In the equation $ydx + xdy = 0$ we are saying: Draw all the equilateral hyperbolas with two given perpendicular lines for asymptotes. In the equation $xdx + ydy = 0$ we are saying: Draw all concentric circles with given center. In the differential equation $(y - px)^2 = \frac{c^2p^2}{1 + p^2}$ we are saying: Draw the lines which will always have a fixed amount cut off between the coordinate axes. They are the tangents of the astroid. In polyhedra we have designs, as the polyhedra whose faces are equal equilateral triangles, which may be the regular tetrahedron, octahedron or ikosahedron. If the faces are equal squares, the figure is a cube. If they are equal regular pentagons it is the dodekahedron. In case the faces are equal rhombuses, we have the rhombic dodekahedron or the triacontahedron. In the undistorted crystal, we have polyhedra whose faces are all alike. There are thirty-two large classes with many special cases. All the Archimedes polyhedra are designs. If we make a design by repeating the elementary crystals, as does nature, we find some 230 lattice forms.

If we turn to arithmetic, we may

study congruences, which are designs, in which all integers are arranged according to their remainder when divided by the module. With twelve as the module, there are twelve residue systems, and of these four, namely, those of one, five, seven and eleven, constitute a special system called the totitives of twelve. Their products will always be totitives, and the list may be generated from five and seven alone. The designs in theory of number become very elaborate. Higher number theory is on the frontier of mathematical evolution. We may take congruences of algebraic forms in the same way. If the module is x^2+1, then the residues are all numbers, all multiples of x and all forms $ax+b$. If we combine them we call them "complex numbers." All numbers of a residue class are equivalent.

If we turn from design patterns to design motricities, we find plenty of examples. The musician creates a fugue, which is essentially a design motricity from a theme or themes to the various forms they are to appear in. If a painter repeats a triangle in differing colors and shapes, he has a design motricity. It is not the shapes and colors that are important, but the change from one to another. Hebrew poetry is largely a motricity design, enunciating a statement which is repeated in different forms to give new suggestions:

> One that ruleth over men righteously,
> That ruleth in the fear of God,
> He shall be as the light of the morning when the sun shineth.
> A morning without clouds;
> When the tender grass springeth out of the earth,
> Through clear shining after rain.

In transformation groups we find motricities, and any mathematical process of combination is a motricity design.

New designs appear in the development of any art. For instance, in music there were tones, then the tonic, the dominant, the subdominant, the major chord, the minor chord, augmented triads, diminished triads, counterpoint, dissonances. The painter learned how to make color vibrate, and even tried to show motion, as in the famous "Nude descending a staircase." In the dance a new expression for the mystic's ecstasy was created, and the rapture of the worshipper of beauty. In mathematics were created non-Archimedean number, infinitesimals—the monads of Leibniz—algebraic fields, automorphic functions, discontinuous functions, nilpotent algebras. What must be created next is a mathematics of consciousness, a theory in which x does not represent a range of values but a range of overlapping moments.

The general theory of rhythm is abstract arithmetic and abstract groups; the general theory of order is abstract geometry and abstract hyper-algebra; the general theory of design is abstract tactic and abstract algorithms; and for the next element, the general theory of harmony is abstract logic and abstract dialectic.

VI. Harmony

We consider the fourth element of the structure of beauty—harmony. On the purely knowledge side it is called consistency. Those harmonies in ideas which we perspicate as worth preserving we call propositions. From these we arrive at concepts, relations, classes, and as one of the very large branches of mathematics—logic. So important a part is it that in 1901 Bertrand Russell went so far as to assert that mathematics is symbolic logic. And for some two decades this simple assertion was so pleasing to the esthetic sense of mathematicians it was often adopted as the final statement of what mathematics is. But the statement has been shown so often to be inadequate that new definitions have been expressed. Indeed, it

is so far incorrect that we must assert that in place of mathematics being logic, symbolic logic is only one phase of mathematics. This is all the more evident when we look at the new logics created in the last decade. "To be or not to be" is no longer the list of possibilities, for it must read now, "to be or not to be or to—what?" Brouwer's work along these lines is very new, and not yet widely read. We still do not consider as harmonious being and non-being, but as a choice between them there are other alternatives. The dichotomy and law of excluded middle of Aristotle, which held the world so long in fetters, are now seen to be but one way of thinking, and the human spirit is creating new ways. What this may mean philosophically is for the future to work out. The law of identity too is gone, and no thing or event is ever again what it has once been. The saying of Heraclitos many centuries ago is seen to be true: "I can never step into the same stream twice."

Consistency is in a curious situation, for there is no test, no criterion, of consistency. We have not noticed so far any inconsistency in ordinary Euclidean geometry, for an instance, but what the future may bring forth we do not know, and the entire structure may some day be seen to be consistent only under conditions not yet stated. There is no criterion for harmony either. What is inharmonious to one age or one people is harmonious to another. Even Schoenberg's dissonances produce a harmony not thought of before. The universe in short is evolving, that is, changing from time to time, and place to place, and man is evolving and acquiring new intuitive power. Indeed, we find the solutions offered by poets, prophets and artists for the desperate problem of evil are solutions which practically say that there is really only harmony in the world and what we call evil is a kind of harmony we have not yet come to see through. It is part of a design we do not comprehend. But harmony was recognized away back in Pythagoras' time as one of the most desired goods; indeed, he says that when we appreciate harmony we shall become as gods.

That we can learn to see deeper harmonies we might exemplify in this way. If we consider a circle, we see of course that every point on it is at the same distance from the center as every other point. This is harmony. But if we project the circle, that is, take its shadow as it is held in different positions in front of a brilliant point of light, the circle becomes an ellipse or a parabola or a hyperbola, and the center becomes a point which is no longer center for anything. The harmony remains, however. The trouble is with our first statement. For if we avoid the word distance, and substitute terms from projective geometry, the center being the pole of the line at infinity, then we see that all statements remain unchanged. If we call the center the intersection of conjugate diameters, the new statement is the same. The harmony remains, but it must be seen from a more exalted standpoint.

We must consider harmony motricities too, and on the consistency side they are the modes of inference we use, the patterns of deductions, whether ordinary inferring or such subtle inferences as those Fermat used so effectively three centuries ago. The essence of these, commonly called "mathematical induction," is simply the intuition of that part of a set of particular facts, which remains independent of other parts. To use James's example, if I say that on a Royal Baking Powder can, the wrapper has a picture of a Royal Baking Powder can, then I know at once that inside that is another picture, and another, and so on to any extent. Or again the lines that connect in succession the midpoints of

the sides of a rectangle make a rhombus, and the lines that connect the midpoints of the sides of a rhombus make a rectangle; therefore, if I continue drawing such lines I will forever have a rectangle or a rhombus. The edges that join the centers of the faces of a cube make an octahedron, and the edges that connect the centers of its faces make a cube. Hence the conclusion. But we can go further, and state that in a certain figure we have drawn with yellow crayon and labeled an isosceles triangle, the equality of the sides demands as harmonious the equality of the two base angles. And since this fact is independent of the size of the triangle, or its particular shape, or its color, we may say that in any isosceles triangle the base angles will be equal. It is easy to see that most mathematical reasoning is of this intuitive and we may say, Fermatian character, which was pointed out some years ago by Poincaré.

As an example of what is meant here by harmony motricity we can cite the symphony in music. It is a composition of many parts, very elaborate sometimes, yet all in harmony. In grand opera we have another example. The theory of rational mechanics is another case, very largely ideal, and treating of situations, forces, and laws not known to exist in nature, but so harmonious a system that physicists were very reluctant to dispense with it, and even yet cling to Hamilton's principle as the one key to all modern relativity physics.

One of the most magnificent attempts at the production of harmony in mathematical subjects is shown in the late E. H. Moore's "General Analysis." For several years he worked on this unifying theory, and in the course of time all his researches will be published. It brings together in a mathematical symphony every part of analysis, so that we deal with a finite number of variables, a denumerable number, or a non-denumerable infinity, all at the same time. It uses matrix theory for explaining any type of integration; and rationality domains, hypercomplex domains, functional domains, all appear to play their rôles.

VII. Conclusion

We now return to the original question: What is mathematics? We are able to say that in the spirit of man, a living, constantly changing, elusive entity, there are elements which produce art and knowledge. If we study what they produce, we find that it is called beauty, and contains elements which we may consider either from the living, dynamic side as elements in the structure as viewed by the artist; or we may look at them from the static side, as knowledge, and name them rhythm, order, design and harmony. Mathematics is, on the artistic side, a creation of new rhythms, orders, designs and harmonies, and on the knowledge side, is a systematic study of the various rhythms, orders, designs and harmonies. We may condense this into the statement that mathematics is, on one side, the qualitative study of the structure of beauty, and on the other side is the creator of new artistic forms of beauty. The mathematician is at once creator and critic, not always, of course, in the same person. It is well known that Sylvester, Klein and Poincaré were great creators, and not much interested in the critical side. Cayley, Hilbert and Picard were magnificent examples of the critical side. Sylvester never knew in a new set of lectures where he would go. Klein was the despair of Hilbert with his flashes of intuitive creation, using any medium for expression that met his fancy. Poincaré always attacked his work with the intuitive eye. But in all great mathematicians from Pythagoras to Poincaré we find the artist character combined in varying degree with the scholar character.

We may also now answer the second question: Why should mathematics interest more than a few? Mary Austin in her "Everyman's Genius" advises all creative artists to study higher mathematics, so does Havelock Ellis. Not of course for the mere scholarship involved, not for the keen intelligence it will promote, but for the high order of imagination it will demand, for the incisive artistic insight it will generate. If, for instance, one studies only the fields in algebraic number which are super-quadratic, having groups of order 2^N, he will learn new things about beauty. If he studies only the field of symmetric algebraic forms he will be charmed with its elegant beauty. The algebra of determinants is a beautiful garden, open on every side to expansion, as one may see in Metzler's treatise. If he finds some new theorems in the geometry of the triangle, he will be thrilled with their beauty. Merely to know of the transversals of a triangle, the Brocard points and Brocard circle, the Lemoine circle, the nine-point-circle, the Tucker circles, the isotomic lines, the isogonal lines and other figures, will bring new beauty to the imagination. In theory of numbers Fermat's last theorem awaits its proof, and will crown with glory the one who gives the proof. Dickson's division algebras furnish a very interesting and profitable realm for new theorems. Why extend the list? It is endless.

Many mathematicians have been artists in other ways. Some wrote poetry, some composed music. The inquiry conducted several years ago into mathematicians' activities found that most of them were seriously interested in some phase of art. And most of them reported that their discoveries or creations came just as do the inspirations of artists in other lines. The mathematician dreams, and in his dream an elusive spirit goes in and out; floats in the mist, and vanishes; glides back at unexpected moments, but slips away from the hand that would grasp her; reappears in an intricate dance, and phantasmal play of color; disappears; and one day steps out to clasp the hand that has awaited her, with Kummer's ideal numbers for a gift. The mathematician dreams and in the spinning chaos fairy flowers in fantastic forms bloom and vanish; mists wind through them with birds flashing now and then; strains like Debussy's nocturnes are faintly heard; a seething, bewildering multitude of forms are created out of the void, they drop back into the void; and then in one rapturous moment a new form appears, superbly beautiful, and Prospero's wand is held stationary to bid the cloud-castle, the flowers, the wild birds, the haunting music, the spirits of light and beauty stay, and a new branch of mathematics is born, the linear associative algebra of Benjamin Peirce. This is an enchanted land, and the city, like Hugh Ferriss' "Metropolis of Tomorrow," is, in Tennyson's words, "built to music, therefore never built at all, and therefore built forever." It is a world that knows no second law of thermodynamics, a world that guarantees to man his creative nature, his eternity of time, his imperishability. Here grows the ash-tree Yggdrasil, supporting the universe, its roots in nature, its trunk of the fibers of logic, its foliage in clearest ether of intuition, its inflorescence the living imagination. In this land of enchantment the queen is beauty, who turns men into gods.

ROMANTIC GOVERNMENT VERSUS UNROMANTIC GOVERNMENT

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THE human animal is an incurable romantic. Other animals seem to view life rather objectively, taking it as it comes and for what it seems to be, but man prefers to view it subjectively, painting it over in his favorite gay or somber colors, dramatizing it, and in one way or another transforming the spectacle and action into something befitting the animal which lives at the center of the universe and is the most important of created things. Through his animistic romanticism he achieves his religion, by chivalrous and gallant romanticism he elevates passion or the routine of marriage to the status of love, and by an admixture of hero worship and fetishism he formulates his governments.

This passion for romanticism in our personal life has some desirable aspects. In its religious phases it has taken form in some commendable ethics and some noble architecture, painting and sculpture. In the field of individual emotions, it leads to pleasant relationships and the works of Lucian and Cabell. In personal matters, the right to romance and romanticism is well within our circle of personal rights. But in government romanticism expresses itself, only too clearly as regards the comfort and safety of mankind, in democracy, autocracy, aristocracy, dictatorship and similar romantic ideology.

It must be admitted that in all probability the romanticism which has colored all government from ancient times to the present was and still is inevitable and inescapable. The reasons for a human behavior that is world-wide and rooted in the ages must be real, profound and convincing. But at this time I challenge the necessity for continuing to regard government from a romantic point of view.

From the romantic point of view, government is a matter of politics, statecraft, diplomacy, principles, tradition, leaders and similar components. All these things can be defined objectively, and all are rich in connotation and prone to arouse warm emotional reactions. To one man democracy is a fetish, and dictatorship an abomination; to another man dictatorship is a fetish, and democracy an abomination. Such emotional reactions have carried governments through alternate cycles of one thing and another, but there is little profit in the alternate testing and disapproving of this and that.

It is proposed here to examine the concepts of government somewhat briefly and critically, not to settle anything whatever, but to present a point of view which is seldom utilized in considering governments. Briefly, we think that governments are not good subjects for romantic treatment, that romantic ideas of government obscure facts that are self-evident except to romanticists, and that an existing move towards unromantic government, a move not generally recognized, should be given consideration as offering something more fitting for modern times and present-day needs.

To make clear the distinction between romantic and unromantic concepts of government and to provide a background for discussion, we define unro-

mantic government as the conduct of the communal business, government that attends to such business as is not attended to by individuals or non-governmental groups, such business as the commonplace routine of public works, roads, taxes and public health. If we look at government in this light, we can regard it as a matter calling for the employment by the state, whether the state be federal or town in scope, of persons well informed and well trained in such subjects as public works, roads, taxes and public health. This simple and unromantic view of government is remote from the accepted views, and we proceed to take issue with those views.

One of the romantic elements of government is the entire concept of politics. It finds romantic expression in the American devotion to a two-party system, supposedly expressive of the Gilbert and Sullivan concept that "Every boy and every gal that's born into the world alive is either a little liberal or else a little conservative." How true this concept of a right and left wing may be can be judged by the national political platforms of our leading parties in 1928, when the left wing, not unnaturally, proved to be a mirror image of the right wing.

The romantic American sees nothing incongruous in selecting as mayor of a city a Democrat or a Republican at a time when a Democrat is defined as a believer in tariff for revenue, and a Republican as a believer in a protective tariff. Obviously, one's tariff beliefs have nothing to do with judging whether Main Street should be repaved, nor does a mayor vote on tariff legislation, but to the romantic American that does not matter.

Romantic government deals in emotionalism, in patriotism exemplified in ritual, ceremony and formula, in international hatreds, in the reform of its citizenry by Mann acts, Volstead acts and similar noble experiments and acts of faith in unbelievable things.

The smart politician is not in the least deceived in this matter. Voters may think that there is a principle at stake in local elections on a national party basis, but the shrewd politico knows that the thing at stake is the question of who gets the office and influence, and, too frequently, who gets the concessions, graft and other perquisites. The smart business man realizes that in a world of romanticists government will control business or business must control government, so he and the politician have an understanding from which romanticism is eliminated.

Another priceless pair of romantic concepts is that of statecraft and diplomacy. These elements of grand strategy are eternally conjoining with the military forces to seize some Alsace-Lorraine and thereby sow the seeds of new wars, all of them destructive to winner and loser alike. Their smartest achievements of to-day are seen in some not remote to-morrow to be stupid and vicious, and it is difficult to find in the long list of statesmen and diplomats any whose judgment and achievements have had historical justification.

Traditions are the special heritage of romantic government. Many of them are immensely valuable to the stage, the movies and literature, since it is undeniably fascinating to find in such places as London the endless picturesque doing of elaborate things for no reason other than that these things were done a thousand years ago for reasons long ago forgotten or no longer applicable. As a spectator one can approve these things almost whole-heartedly; as a citizen one could ask that they be transported from the field of government to the field of histrionics, where they belong. Traditions ennoble not merely the gaudy and useless, but also the preposterous and iniquitous. They tie us with the fetters of dead men, dead beliefs, dead emotions. They close the avenues to change, experimentation and progress, and force

on the unromantic element of government the rôle of iconoclast.

At this time the world is in a mad search for leaders, and the supply of leaders is, as usual, quite equal to the demand. Leaders are such a simple solution for a lot of baffling problems. They answer all the moronic demands of bewildered minds for a Moses to lead them to some Promised Land, for a magician who can solve all problems, national and international, by the magic of personality and leadership. It is a comforting idea to romanticists, who find that thought is conducive to headaches, and hard work productive of backaches. The history of the world's leaders shows that if the mob will follow, leaders will lead them somewhere, but not to the land of heart's desire. A Peter the Great may learn ship-building and lead in that art a people that are not ship-builders, but in general the political romanticist wishes nothing so simple and so difficult. He wishes leaders of an inspirational sort, who by inspiration know the answers to the questions of tariff, coinage, transportation, communication, immigration, international trade and such bagatelles of government. The realist in government does not wish to be led; he wants trained, capable, intelligent, honest public officials who will attend to the public business.

Among the romantic concepts of government is democracy. Democracy is too valuable to be subjected to the fetishistic treatment of romanticists, for this sort of treatment endangers the existence of realistic democratic government. Democracy has this valuable characteristic: It ensures individual safety as no other forms of government have ensured it, and on that one score alone democracy should be saved from its friends and its foes alike. It is notorious that democracies have often proved inefficient, but thousands of years of dangerous autocracy of one sort and another have driven nations to democracy. All Latin America knows that when dictators have destroyed the machinery of democracy elections must be by revolution, and that revolutions are the inevitable sequel to dictators.

Nevertheless, we have the swing to the romantic concept of the ancient cult of the dictator, the Man on Horseback. It is astounding to have in modern times this recrudescence of belief in the Able Man, with its flavor of divine right of kings, of the law of lése majeste, its suppression of opposition, criticism, alien groups and the like. To a realist there is nothing surprising in a band of vikings hailing as leader their best fighting man, for theirs was a government that dealt in war; these men were realists, the greatest warrior was their expert in government, and he gave them precisely what the realist wishes, expert government. To-day, the dictator is an anachronism, the skeleton of an ancient realist dug up by romanticists and set to rule over romanticists. Your hero worshipper has the faith of all romanticists, the faith that a dictator can know all the complex business of government. To a realist it seems evident that dictators are too small for the large job of government, and too impermanent for its long-time needs.

It is said that dictators are efficient. To this assertion the realist may cock an incredulous ear. It is admitted that dictators have the unimpaired authority to do things that their title implies. It is admitted that they do the things they wish to do. But it is not admitted that doing what one wishes to do is efficiency. A child may break its toys quite painstakingly, and not be efficient or admirable. Efficiency in government implies not only that things are done but that these things are desirable things and are for the general welfare. On any such basis we note that dictators, unpredictably, may do preponderantly good things, or preponderantly bad things,

or, as in the case of Napoleon, may balance a Code Napoleon and some good roads against devastating wars and "forty battles won." On the whole their record of efficiency is little, if any, better than that of democracies. Against any efficiency dictators may exhibit, we set the fact that the dictator is dangerous to the life, liberty and happiness of the citizens he governs. He imposes on them the necessity of agreeing with him or suffering, a thing for which only a romanticist can hurrah; your realist in government, who believes the whole greater than any of its parts, finds this a droll concept of a government attending to the communal business by molding a nation in the form of one of its citizens. One can see the workings of a dictator to very great advantage in the small-scale operations of a Latin-American country, and having seen it on such a small scale the realist will not wish to see it on a larger scale. The romanticist, of course, will continue to find Diaz of Mexico, Emiliano Chamorro of Nicaragua and Machado of Cuba admirable dictators, just as he finds Caesar, Tamerlane, Napoleon, Mussolini, Stalin and Hitler admirable dictators. As individuals these men may have great charm and ability, but the unromantic realist will look askance at all dictators as dictators.

As a realist in matters of government, I speak now for unromantic government. For a quarter of a century I have participated in the unromantic government of the United States, and, at the same time and at close range, have been a spectator of the romantic government. During that time romantic government has been represented in the White House by the strenuous Teddy Roosevelt, the judicial Taft, the scholarly Wilson, the genial Harding, the calm Coolidge, the engineer Hoover and Franklin Roosevelt, whom history will characterize better after all the returns are in. It is sufficient to name these men, to recall their characteristics and the manner and reasons of their accession to power, to see how romantic government functions. Do you recall how up to a certain March fourth, each of them was to almost half our citizens the embodiment of all objectionable things, and how after that certain date each became imposing, oracular and incredibly important? This is magic, the magic of the romanticists.

And in the same period, who constituted the unromantic government? During that period the unromantic government consisted of bureau chiefs, division chiefs, editors, scientists, physicians, veterinarians, lawyers, officers and men of the army and navy, clerks and other workers. You probably know little about the personnel of this unromantic governing group, but you may recall Goethals, Gorgas, Reed, Carroll, Asaph Hall, Peary, Byrd, Stiles, Walcott, Stratton, Galloway, Taylor, Mohler, Harvey Wiley, Gifford Pinchot, L. O. Howard, Goldenweiser, Durand or Atwater as some of the distinguished representatives of unromantic government.

And what did these realists in government do? They proved that yellow fever was carried by mosquitoes, they drove yellow fever from the Isthmus of Panama, and they built the Panama Canal; they lessened the incidence of amebiasis, malaria and hookworm disease; they developed high-frequency radio communication; they gave over 5,000 bearings a month to merchant ships to make navigation safer; they devised the sonic depth-finder for rapid surveys of ocean depths; they invented smokeless gunpowder; they provided precise time for surveying, astronomy and gravity determinations; they published the *Nautical Almanac* and *American Ephemeris;* they conquered the North Pole and the South Pole; they brought relief to sufferers from pellagra and Rocky Mountain spotted fever; they developed the anticlinal theory and the

carbon ratio theory for the use of the petroleum industry; they devised a system for the blind landing of aircraft; they supplied data for ventilating the Holland Tunnel; they built the tide-calculating machine which, with one operator, does the work of 70 mathematicians and saves $150,000 in salaries annually; they developed disease-resistant plants; they introduced durum wheat into this country; they synthesized ammonia directly from hydrogen and nitrogen to make fertilizers; they developed control measures for dust explosions and lowered insurance rates; they found a method of making furfural for 10 to 17 cents a pound instead of $30 a pound; they found that Southern cattle fever was carried by the cattle tick, and they drove the tick from over 89 per cent. of its range and are driving it from the parts of those states where it makes its final stand, saving $40,000,000 annually for a total cost of less than $40,000,000; they developed a treatment for human hookworm disease, and for hookworm disease and heartworm disease in your dogs; developed the hog cholera serum which saves millions of dollars worth of swine annually; they protected you from adulterated foods and inert drugs; they inspected your meats; they compelled the adoption of safety devices on railroads, ships and airplanes for your protection; they supplied expert information on finance, tariffs and similar subjects; and in a thousand ways they carried out the communal business, the work of the United States Government, the unromantic government that is overshadowed by the more gaudy and vocal romantic government.

The personnel of this unromantic government is selected by Civil Service competitive examination on the basis of education, experience, training and knowledge. Any one of several qualified persons at the top of a list may be appointed to a position, but all these persons are qualified. Compare this with our romantic government, elected on a platform of ballyhoo, favorite sons, stupid slogans, election promises, vilification, innuendo, such magical cantraps and abracadabras as will most certainly enchant the romanticist, and such doodads, dingbats and thingumabobs as will delight the grown-up children. Does this system secure qualified persons? Perhaps it does in your party, but it quite obviously does not in the other party.

The unromantic government is expert government. In the list of names given here are many of men who are rated as the best or among the best in the world in their field. Most of them had this rating when they were being paid from $1,400 to $5,000 a year. How many Congressmen selected on the romantic basis of politics are the best or among the best in the world in their field? How many have an expert rating in any field? Offhand I recall a few, such as Senator Copeland, an expert on public health, this rating dating back to the days when he was part of New York City's unromantic government, and Senator Glass, an expert on banking.

But, you may ask, what of it? We have two kinds of government; granted. So what? I answer: Why not abolish the romantic methodology and substitute the unromantic? How? Continue to substitute the professional non-political type of government for the political non-professional type, and keep on until the professional type is carrying on all the nation's business instead of sharing it with the political type. How could this be done? By the extension of a sound civil service or other merit system, gradually encroaching, as it has in the past, on the field of the spoils system, of the political henchman and of political nepotism, until romantic government is replaced by unromantic government. We should lose nothing from our romantic selections except the incompe-

tents, as the competent would be more certain of selection under a merit system.

Does this seem difficult? It is no more difficult to hold a Civil Service examination for a sheriff than for a geologist, for a judge than for a psychologist, for a congressman than for an economist, for a president than for a sociologist. Let us grant that you can name a half dozen presidents, selected by romanticist measures, whom you regard as highly competent presidents; you can also name a half dozen whom you regard as highly incompetent. Unromantic government would retain all the safety of democracy by allowing the electorate to vote for presidents, but would eliminate the inefficiency of democracy by limiting the candidacies to qualified candidates only, so that regardless of who was elected the president would be a qualified person. Such a system would not get ideal executives, but it would eliminate preposterous persons from the presidency, governorships and mayoralties. It would ensure that judges were competent in judicial matters, and that legislators knew something of law-making and were never elected merely as good fellows, handshakers and donors of cigars.

The objections that will occur to you are easily foreseen. Some persons without education, training or experience, but with qualities of leadership, would be disqualified. However, the unromantic realist will refuse to weep if there is never again a Jackson in the White House. Jackson fitted his era, but the era is over and we face complicated problems through which no amount of hard-headedness can butt a way. Courage alone will not solve banking and monetary problems.

Another objection is that this unromantic government is merely bureaucracy under another name. There would be good grounds for this objection. Bureaucracy is government by bureaus, according to definition, and on this basis you have bureaucracy already, since a half million persons, from admirals, generals and bureau chiefs to the doughboys, gobs, mail carriers and messengers, quietly carry on your bureaucratic government twelve months in the year, while your romantic government puts on its lesser and noisier show for a small part of the year and then joyfully rushes home to take up its more serious occupations.

But bureaucracy may have an unpleasant connotation, and this unpleasant term is defined as officialism with officials endeavoring to concentrate power in their individual bureaus. Speaking as a bureaucrat, in the sense of an officer in a government bureau, I note that in the government bureaus one finds about the same variety in ambition that one finds elsewhere, some officials being satisfied with small organizations and some desiring large organizations. There is little damage evident in either case, but it is evident that a too small organization may be inadequate for the demands made on it, just as a large organization may be too large for the demands on it.

But, you may say, bureaucracy implies officiousness. Admittedly, we occasionally meet with officiousness, usually on the part of lesser and relatively unimportant persons, among bureaucrats as among bankers and ribbon clerks. Officiousness is a nuisance, and nuisances are objectionable. But if we weigh the nuisances of our unromantic government against the dishonesty of some romantic administrations, the stupidity of some others and the danger from fanatical legislation in some others, we must see the officiousness of a minor bureaucrat as the least of the evils named.

In the high but not so far-off days of the spoils system, when all American politics was romantic politics, one section of the government service was known as The Harem, and there were

Congressmen's lady friends who were paid as artists, although they never drew anything except their salaries. Finally, a disappointed office-seeker shot a President, and a Civil Service that should have been born earlier of common sense and realism was born of anger and grief. The political romanticists provided that the unromantic government it had created must keep out of the romantic side of government. Why? Because political romanticism was ruinous to efficiency and unbiased honesty. It was not noticed at the moment that political romanticism is quite generally ruinous to efficiency or honesty or both, and not merely in the civil service. It is, of course, as ruinous in a legislative body as it is in a scientific laboratory. A really able legislator, La Guardia, has said: "The most humble research scientist in the Department of Agriculture is at this time contributing more to his country than the most useful member of Congress." If this is even partially true, it is because the selection of legislators on a romantic basis can be depended on to turn up very few La Guardias, whereas a merit system of selection, such as the Civil Service, can be depended on to turn up qualified persons with great regularity.

By virtue of the prohibition of activity in the field of romantic government, and by virtue of residence in the District of Columbia which deprives them of their right to vote and ensures that they will be taxed without representation, the Washington representatives of our unromantic government may be said to have been deprived of their political rights. Now, there is no fetish more dear to political romanticists than political rights. Undoubtedly they are important. But just what are our political rights? Are they what the political romanticist thinks they are? Are they the right to shout and write for this, that or the other action on subjects of which the romantics know little or nothing, and ultimately to vote for persons with whom they agree and who likewise know little about these subjects? Apparently they are just these things. And is this important or valuable? Was all the oratory and ink that went into the McKinley-Bryan campaign of 1900 of any more value and benefit than the concurrent debate as to whether the century began in 1900 or 1901? Was all the Coolidge-Davis debate and controversy of more importance than the question: How old is Ann?

There are certain personal rights which are of value. One is the right to be safe in one's person, liberty, property and freedom of expression within the bounds of law and of consideration for the rights of others. If this right is important, dictatorships of all varieties are intolerable. There are certain political rights which are of value. One of them, not generally recognized, is the right to have only qualified persons appointed to office or presented to the electorate as candidates for office. This is a very different thing from fetishistic democracy and all other forms of political romanticism. Political romanticism allows one to appoint officials and to vote for candidates regardless of qualifications, and the right to do this is a highly cherished right of fetishistic democracy. In religion one must have the right to go to hell if one does not wish to go to heaven, but that is a personal matter. No such option should be tolerated in government. In the field of politics we can maintain our personal rights only by maintaining the community rights, and it is a violation of the community rights to permit unqualified persons to govern.

Hence we may say that our Washington representatives of unromantic government have been deprived of nothing of value in not being allowed to vote for Tweedledee instead of Tweedledum, or for a second-rate orator instead of a third-rate orator, or for any of the other

offerings of political romanticism. However, they have been deprived of the right to have only competent persons appointed or presented to the electorate, and this is a serious matter, as it exposes them and the majority of our citizens, if not all of us, to the stupidities and iniquities of incompetent romanticism.

For a couple of years, we of the bureaucracy have been under fire from the romantic politicos and the business magnificos. Having discussed the politicos, I speak briefly of the magnificos. The lack of qualified persons in business is quite as impressive as in politics, and the magnifico is as much of a romantic as the politico. For thousands of years the only essential for engaging in business has been to have the necessary capital or be able to get it, and the principal qualification of the business man has been his ability to buy for one dollar and sell for two dollars. It is only too evident that one can be a banker without knowing the elements of banking, can engage in transportation without knowing anything about transportation, can own and operate drug factories and drug stores without knowing strychnine from Seidlitz powders, and can simultaneously be a banker and a bank wrecker, a railroad magnate and a railroad wrecker, the owner of a chain of stores and a dealer in poisoned products. This right to engage in business ignorantly and dangerously, and become unlimitedly rich at it, seems to be the essence of rugged individualism.

The proposals of the politicos for ending the depression, by and large, have been exceeded in vacuousness and inanity by the proposals of the business men. We demand certain qualifications of physicians before we let them practise, and we even require that plumbers know something about plumbing, but we risk our lives on many things we buy and never ask that the man who takes our money establish any qualifications for his business before he is permitted to engage in it. This romantic confidence in the business man has been justified in some individual cases, but too often it has been a prolific source of robbery, poisoning, homicide and other high crimes and misdemeanors. That it is not a more prolific cause of these things is due largely to the functioning of the unromantic government.

I said the business magnifico is a romantic. He is. He still carries with him his childhood patterns of behavior in his belief that much money is a good thing, and that wealth and power are roads to happiness, in spite of the fact that innumerable rich men have testified and their careers have demonstrated that the road to happiness assuredly does not lie in the domain of Midas or Caesar.

And since we are dealing with romantic government, what do we mean by romantic? According to the dictionary, romantic is relating to romance; fanciful; visionary; fictitious and improbable; fantastic; sentimental. Romance is prose fiction, an extravagant story, things strange, fascinating, heroic, adventurous or mysterious. These things are the essence of romantic politics—the spells of the spellbinder, the painfully concocted ambiguities of political platforms, the campaign promises, the sentimental misuse of the Washington, Jefferson and Hamilton traditions, the mysterious misdeeds of opposing parties and candidates and the rest of the propaganda regarding our fictitious virtues and our opponent's improbable vices.

As regards things fanciful, visionary, fictitious and heroic in politics, the writer has this thought in common with Stalin, Mussolini, Kemal Pasha and Hitler, that political parties should be abolished. But where the dictators' solution is merely a change from the romantic plural to the romantic singular, from fanciful parties to one allegedly heroic party, the writer would go far-

ther and abolish all political parties, leaving only the professional force charged with the serious, commonplace business of government.

What is the prospect of our giving up our romantic government in favor of unromantic government? There is a fair prospect. The unromantic civil service and other merit systems are actually making headway, slowly but surely, against romantic government. The United States and Britain have sound civil service systems, extending in Britain up to under secretaries in the cabinet, and just stopping short of assistant secretaries in the United States. A few of our states have merit systems, some of them effective. A very few counties have merit systems. Among our cities, 445 have changed from the romantic mayor to the unromantic city manager, and 165 other cities have city managers of limited responsibility. Historians may find that the greatest advance of Franklin Roosevelt's administration was his employment of expert advisers in economics and sociology.

Even more striking is the growth of unromantic government in the U. S. S. R. The romanticism of sovietism and dictatorship has held the attention of the world, but the really startling development is the rapid, sound and extensive establishment of unromantic and expert government in that country. Starting out with a drive against the professional groups, the Soviets soon revised their attitude and began to seek out and to develop experts. At present the high positions in engineering are held by engineers, and farming is under the control of agricultural experts. In my own field, veterinary parasitology, the United States has held the commanding position for years in the size of its Federal scientific staff and the extent of its effective measures for the control of parasites of animals, and imperial Russia was without competing personnel in this field. Within ten years the U. S. S. R. has moved to first place in size of scientific staff, far exceeding that of other countries, is putting out an unusual amount of good work and is beginning to forge ahead in its extent of control. In the field of unromantic government the U. S. S. R. promises to excel all other nations so greatly that the only competition will be for second place. If unromantic government is as superior to romantic government as I believe it is, here is the point at which the U. S. S. R. promises to educate the world on the subject of government. It seems entirely probable that the U. S. S. R. may be the first country to supplant romantic, political, non-professional government by non-romantic, non-political, professional government.

Romantic government has a strong hold on a humanity that reluctantly ceases to play with its toys. Mankind does not quickly give up its torch-light processions, its love of royal pageantry, its affection for the catchwords of democracy or autocracy, its belief in the magic of politicians, its desire for leaders to find the way to happiness along some road that does not involve thinking or hard work. But in time it does give them up. The torch-light processions are gone, in most countries the thrones have fallen, and although we still play at romantic democracy, indulge in the ceremonials of the fascist salute or the adoration of the Hakenkreuz, and still manifest faith in political promises and leaders, we shall come, sooner or later, to a realization that accomplishment of our ends lies in the direction of sound thinking and hard work. We shall employ more trained thinkers and competent workers, not as adjuncts to romanticists temporarily in office, but as the real and permanent government. We shall in time abandon romantic government, as we have abandoned fire worship, witchcraft and medieval chivalry, in favor of unromantic government by qualified persons only.

HUMAN RECAPITULATION

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THE course of embryological development suggests, in broad outline, the ancestry of the individual. The tendency on the part of the individual organism to pass through ancestral evolutionary stages is called recapitulation. The individual rapidly climbs the tree of ascent, repeating in his development the stages through which his ancestors have passed. Several traits of unsophisticated prenatal development suggest brief adherence to ancestral type.

The early embryonic structure of man is as undifferentiated as the structure of the amoeba. Later the individual exhibits the bilateral symmetry that characterizes the vertebrates, but for some time is a non-vertebrate animal, little differentiated in structure, with no complexity of parts. After the appearance of the vertebral column, or of cartilaginous centers which will develop into the vertebral column, there is a further differentiation of parts. Gradually the prenatal structure takes on the characteristics of a vertebrate mammal. There develop the so-called gill-slits, which are interpreted as corresponding with the gill-slits in fishes. These appear not merely in man but in the embryonic stages of reptiles, birds and all mammals. One pair of them develops into the Eustachian tubes, so that later they actually do perform a function.

The so-called milk lines along the chest of the embryo suggest a record of a time when man's ancestors, or at least ancestresses, had more than the single pair of nipples which characterizes our contemporaries. During prenatal life the nipple is much higher than it is on the contemporary adult; though a comparably high nipple is found normally on adult apes and other Primates. In the wrist of the embryo there appears a carpal element known as the *os centrale;* this disappears before birth, but in some of the anthropoid apes (the orang and the gibbon) and in many of the lower vertebrates it persists through life. The young embryo has from 7 to 9 vertebrae in the caudal region, whereas adult man, tailless, has only 3, 4 or 5 coccygeal vertebrae. In a human embryo of 7.5 mm crown-rump length, the percentage of length of tail is 16 per cent. of this dimension, whereas in adult man the length of these vertebrae is only about 3.5 per cent. of this dimension (sitting-height). The orang-utan, however, has only 2 or 3 coccygeal vertebrae—less than the average in man.

In the fetus of the genus *Colobus* and in *Hapale jacclius,* a primitive South American marmoset, vibrissae develop on a hillock of the skin, where they receive a branch of the ulnar nerve, and hence are regarded as primitive touch organs. In man this hillock occurs, apparently in only a small percentage of cases, in an early period of prenatal development. The hillock contains no sinus hairs and disappears during the ninth week of fetal life. This rare and ephemeral carpal hillock has been interpreted as an atavistic structure in the human embryo. Its only known functions is to remind us that the trait probably was present in our remote Primate ancestors.

The position of the phrenic nerve, which innervates the diaphragm, is interpreted as a survival from early ancestral stages. This nerve, as in the fishes, rises high in the neck. In the fishes the gills and heart are close together, under

the mouth. "As the gills changed to lungs, and an airtight compartment was provided for them, they moved downward, the diaphragm preceding them. But, as a matter of the most exquisite interest, the nerve which innervates the diaphragm, the phrenic, still arises high in the neck, and, traversing the entire chest at great waste, is the string which shows us where the diaphragm was and its pathway of migration during the ages."[1] Similarly, the lanugo, the hairy coating over the foetus, is assumed to represent the appearance of remote Primate ancestors.

There is also a progressive rotation of the foot upon the leg. In the prenatal condition the surface of the foot turns inward. Gradually the foot rotates on the ankle, the plantar surface assuming a plane more nearly at right angles to the sagittal plane of the tibia, although at birth the feet still turn inward.

In the human embryo the upper limbs are relatively much longer than in the new-born, and they become relatively shorter in youth and adulthood. The arms of the gibbon, on the other hand, are relatively short in prenatal life, and increase in length with growth. In the prenatal period, the arms of the gibbon, in proportion to body length, are, in fact, not much longer than those of the human fetus in proportion to body length.

Even after birth there are suggestions of recapitulation. The child can not walk until it is several months old. It can, however, go on all fours, that is, be a quadruped, before it can walk on two feet, that is, be a biped. Moreover, in the early stages of its earthly career, it is practically a quadrumanous creature, for its toes and feet are almost as mobile as its fingers and hands. With its toes it can grasp objects with almost the facility with which it can grasp them in its hands. When it learns to walk, the toes are turned in and the child walks largely on the outside of the foot, much as does an anthropoid ape. This inability to walk on two feet is accompanied by a remarkable power of handgrasp. A child two hours old can maintain its weight by overhead handgrasp for about a half minute. At the age of six weeks it can maintain its weight for about two minutes, that is, as long as can the adult who has given no time to the acquisition of this art. In view of the fact that most animals are able at birth, or soon afterward, to walk, crawl, swim or fly, in the manner of progression characteristic of their species, the absence of the ability to walk on two feet, and the corresponding ability to maintain the weight of the body by overhead handgrasp, are very striking. The only explanation seems to be the inheritance of adaptations which are no longer of much use to man, but which were of use to remote ancestors. Man is so conservative of the old, and so tardy in adopting the new, that he requires more than a year of postnatal existence to acquire the upright posture; and when he has acquired it, it is, for a few years, a very uncertain posture.

Yet, though many of the developmental changes from embryo to adult are in keeping with the supposition that the individual recapitulates ancestral history, certainly many of the changes are not consonant with that supposition. For example, during early prenatal life the height of the head is approximately one half the total body length. The proportion of height of head and of size of head to size of body decreases throughout the prenatal period and through much of postnatal life, at least until adulthood. At birth the size of brain in terms of size of body is about three times its proportionate size in adult life. That is to say, through much of the period of prenatal and postnatal development man

[1] Logan Clendening, "The Human Body," 107–108.

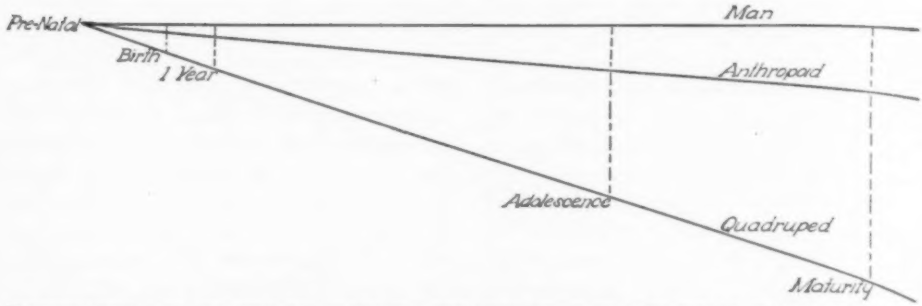
acquires less brain in terms of body size. This, of course, is contrary to the general story of evolution, which shows an increase in relative size of brain from the lower creatures to the higher, from non-Primates to Primates, and from most of the lower Primates to man.

Another fact often introduced to support recapitulation is the similarity in prenatal development between species assumed to be closely related, such, for example, as man and the anthropoid apes. That the close parallelism in development between most mammalian forms implies recapitulation must be doubted. Much of the similarity is the result of independent causes or, at least, would result from independent causes were there no common ancestry. Mammals start with similar structures—the (comparatively) undifferentiated germ plasm. They can develop only from undifferentiated structures to differentiated. In early prenatal development there will necessarily be considerable resemblance between man and ape, and even between man and quadruped.

Of necessity, too, with individual development the differences between the representative of one species and that of another will increase. Some of the similarities in early ontogenetic development, therefore, would be present if man and ape had evolved in different solar systems and had no common ancestry. Since man and ape have similar structures, it follows that the resemblances between them during embryological development will be greater than the resemblances between man and any other animal. They develop in similar prenatal environments, and their respective goals are not far apart; hence the paths which they traverse will diverge less than the paths traversed by man and any other animal. At birth they will be more alike than during adulthood, because the typical species characteristics do not develop until adulthood. In so far, then, as such resemblances are inevitable because of the circumstances of development, they must be regarded as similarities due to the operation of similar factors, rather than as due to common ancestral influences. The fact, for example, that people tend to eat at the same hour is due to the operation of individual causes, that is to say, to the responses of their individual organisms to circumstance, and not to ancestral influence. A similar observation applies to much of the evidence adduced in support of recapitulation.

A like observation applies to the argument that the procedure from simple to complex, from unspecialized to specialized, during embryological development, is the result of ancestral influence. It is true that the early stages of embryological development are comparable with early and primitive forms of life, and that the later stages of prenatal development show greater complexity of structure, as do later and higher geological forms; but the explanation of the resemblance probably lies in the logic of necessity. It is inconceivable that life should start in highly complex form. It is inconceivable, too, that the development of individual structure should start with a highly complex form. In either case, the procedure involves the necessity of passing from the less complex to the more complex, from the little differentiated to the more differentiated. Only those resemblances, therefore, which are not due to parallelism, or to the preconditions of development, imply ancestral influence. Resemblances which would exist even if there were no ancestral influence can not be interpreted as due to recapitulation. The "law of parsimony" applies here.

The matter can be illustrated by the accompanying figure. Development of man, anthropoid and quadruped starts in a similar undifferentiated plasm. The characteristics of the respective species



ILLUSTRATING THE NECESSARILY CLOSE RESEMBLANCE BETWEEN INDIVIDUALS OF ALLIED GENERA DURING EARLY ONTOGENETIC DEVELOPMENT.

appear gradually, and resemblances are necessarily greatest during early development. At birth the differences are greater, and at maturity they are most marked. Conversely, resemblances are greater at birth than in adulthood, more marked during later fetal development, and most pronounced in early embryological stages; and, almost of necessity, the resemblances between embryos are greatest in the case of species which are most closely related. If we apply the same logic to the anthropoid as to man—and we should extend that charity—the anthropoid recapitulates human ancestry; for the further back one traces anthropoid ontogenetic development, the more humanlike are the anthropoid characteristics. The logic which suggests that man recapitulates anthropoid ancestry suggests also that the anthropoid recapitulates human ancestry. At birth, and even in prenatal development, the human individual has certain so-called human characteristics in a larger measure than at maturity. This is notably the case with regard to size and shape of head, which is proportionally larger in prenatal stages and at birth than at maturity; at birth there is considerable cranial development and correspondingly little facial development. These changes in proportions run counter to the traditional implications of recapitulation. Since size and shape of head and the proportion between facial area and cranial area are considered important human characteristics, these traits of infancy can not be lightly passed over when weighing the recapitulation argument. Indeed, if one accepts recapitulation, much of the prenatal and early postnatal development implies that man's ancestry developed from a more human to a less human form, that is, from humanlike to anthropoid apelike, for in ontogenetic development the human individual acquires relatively less brain, proportionally greater supraorbital prominences and proportionally lower cranial vault. In relative head size in terms of trunk length, the *cebus apella,* one of the lower primates, exceeds man by about 8 units. The average diameter of the head

$$\left(\frac{\text{length} + \text{width} + \text{height}}{3}\right)$$

is in the human adult about 31 per cent. of trunk length. In the human newborn this percentage is about 57, while in the newborn gibbon and orang it is about 61. If these proportions are important in comparing man with ape, and contemporary man with prehistoric man, they deserve consideration when weighing the implications of recapitulation. Much of the postnatal development interpreted as implying recapitulation has, in fact, an easier and more obvious ex-

planation in the conditions inherent in development. The strong grasp of the newborn infant suggests inheritance from an arboreal ancestor, because it is greatly disproportionate to the infant's needs; but the approximately uniform curve of spinal column, anteriorly concave as in the ape, may be attributed to prenatal environment and posture. When the child ceases to go on all fours and walks erect the sigmoid curve develops, in response to the new need. The recapitulation theory is deductive rather than inductive, the *a priori* creation rather than the empirical finding of Müller and of Haeckel. Haeckel admits this, and indeed, boasts that the theory is *a priori*. The facts are forced into this scheme, the evidence is not judiciously weighed, and other interpretations are not considered. When Haeckel cited von Baer's position he deliberately suppressed the fourth conclusion of von Baer. This was: "Fundamentally the embryo of a higher animal form never resembles the adult of another animal form, but only its embryo." The reasons for that resemblance, at least sufficient reasons for it, have been indicated in the above paragraphs.

Thus, much of the resemblance between prenatal development in different genera is a sheer result of the laws of growth. Many of the "facts" of recapitulation, then, resolve into analogy and homology rather than into genetic relationship. The development of the embryo is determined not so much by its ancestral past as by the potentiality of the germ cells and by the goal common to its species. Its own organism determines its development—entelechy rather than ancestral influence—for a drive toward specific development is a potentiality of the embryo. Ontogenetic development in different genera is, therefore, determined by different specific causes. As it is not a common pervading hunger, but the independent demands of the respective organisms, which induce men to eat at about the same intervals daily, so no common ancestral influence drives embryological development along similar lines, but similar independent causes which operate in similar ways upon similar organisms with similar results. The recapitulationist sometimes confuses generic cause with specific independent causes which are similar and disregards the fact that the embryo as well as the adult has evolved.

A case in point is the gill-pouches (usually called gill-slits) which appear in the embryo of reptiles, birds and mammals. It is well to remember that "these structures resemble nothing so much as the gill-slits or gill-pouches which appear in the *embryonic* stages of fish. The gill-pouches of embryo reptiles, birds and mammals, do *not* resemble the gill-slits of the adult fish. Any one who can see can convince himself of the truth of this. All that can be said is that the fish preserves and elaborates its gill-slits, while the reptiles, birds and mammals do not preserve them as such, but convert them into other structures such as the Eustachian tube, the tonsils and the thymus glands. There *is* a similarity between the embryos of fish and of reptiles, birds and mammals, but the later stages of ontogeny have diverged. In the reptiles, birds and mammals, other adult stages have been substituted for the adult stage of the fish. During the phylogeny of the reptiles, birds and mammals, therefore, factors have arisen in the ontogenies which control the development from the embryonic stage onwards and which have produced progressive deviation."[2]

As Guldberg and Nansen remark, regarding the embryological development of the dolphin, "the embryo's development proceeds by the shortest road to its

[2] G. R. de Beer, "Embryology and Evolution," 47–48. Oxford, Clarendon Press, 1930.

goal. . . . The embryo seeks, by the most direct way . . . to attain to the special likeness of its parents, or to the specific form."[3] "It is the function of the embryo," remarks Shumway, "to become an adult without looking backward on ancestral history."[4] The embryo is, in large part, "a builder which lays one stone here, another there, each of which is placed with reference to future development."[5]

"If," to quote Gregory, "the biogenetic law were universally valid it would seem legitimate to infer that the adult common ancestor of man and apes was a peculiarly hermaphroditic animal, that it subsisted exclusively upon its mother's milk and that at an earlier phylogenetic period the adult ancestor was attached to its parent by an umbilical cord. The absurdity of this inference shows that the universal validity of the biogenetic law may not be taken for granted, and that in each instance the supposition that a given ontogenetic character is primitive requires independent evidence. If the biogenetic law were without exceptions, the marvelous processes of ontogenetic development would have only a historical or reminiscent aspect and not an anticipatory or adaptive one, since they would all be directed solely towards preserving a clear record of earlier adult states rather than towards the production of viable animals."[6]

In many respects man is tardy in developing the traits which distinguish the anthropoid apes; that is, he does not acquire until adolescence or adulthood some traits which are found in the anthropoid apes soon after birth or even during prenatal development.

Among these traits are the dentition, which is slower than in the ape; the prognathism, which is more marked in the human adult than in infancy; the hairy coat, which becomes more marked in man as growth proceeds; the pigmentation, which in man, especially in the dark races, increases after birth; the eyebrow ridges, which are not elevated in man until after adolescence; the projecting lower jaw, which becomes more prominent only after the permanent teeth have appeared; the spread of zygomatic arches, which increase with growth; the closure of the sutures of the skull, which is more delayed in man than in the ape. In his development, however, man becomes less like the ape in some respects, as notably in proportion of length of lower limbs to stature or to arm length, and more like the apes in certain other traits, as notably in those which have been listed above. If man recapitulates an apelike ancestry, he is, in general, rather tardy about it, and does not reach the end of the journey before old age overtakes him.

[3] Gustav Guldberg and Fridtjof Nansen, "On the Development and Structure of the Whale," pp. 23, 39. Bergen, Bergen's Museum, 1894.

[4] Waldo Shumway, "The Recapitulation Theory," *Quarterly Review of Biology*, 7: 98, 1932.

[5] F. R. Lillie, "The Embryology of the Unionidae," *Journal of Morphology*, 10, 1895.

[6] William K. Gregory, "The Biogenetic Law and the Skull Form of Primitive Man," *American Journal of Physical Anthropology*, 8: 375–376, 1925.

THE ROMANCE OF COMMON SALT

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NOTHING is said in the Bible concerning the addition of salt when Adam and Eve were created, although we know now that they could not have lived without it. Considering the scientific data relating to the appearance of life on the globe, especially the manner in which it was for ages maintained in the saline waters of the Paleozoic seas, we may mark the evolutionary evidence of the survival in man of this early ancestral element. In the earliest geological strata showing fossils, there are found only shells of sea animals and a few bones of fishes. These findings make it seem quite clear why there could be no life as we know it without salt.

In ancient times, salt was rare in inland countries and looked upon as a great delicacy. Governments frequently controlled the supply of salt. This has been notably true of China. The manufacture and garnering of salt was once the work of kings. Kingdoms went to war over the possession of salt deposits. There were some salt springs on the bank of the River Saale in Frankia over which two countries fought for fifty years, believing that such places are closer to heaven and prayers of mortals from thence more easily heard. Even in recent years, riots and bloodshed have occurred in Ecuador because of a salt famine resulting from damaged transportation. That salt had a deep religious significance to the ancients, there can be no doubt. Homer calls salt "divine" and Plato names it "a substance dear to the Gods." Moses admonished the children of Israel that "every oblation of thy meat offering shalt thou season with salt; neither shalt thou suffer the salt of the covenant of thy God to be lacking from thy meat offering; with all thine offerings thou shalt offer salt" (Lev. 2: 13). Salt had a symbolic significance by the Jews in the ritual of the covenant (Num. 18: 19). We can well imagine the consternation of the populace as Lot's wife was turned into a pillar of salt when she disobeyed her husband and looked back (Gen. 19: 26). Commentaries on the fate of this unfortunate woman recite the commonplace explanation that she was suffocated by a dashing spray of sulfurous salt which encrusted her whole body. In early America, the Hopi Indians gathered salt from a deposit in the Grand Canyon with great ceremony by making sacrifices to the Goddess of Salt and the God of War. The Zunis had a "salt mother" who was the genius of their sacred Salt Lake. There is a legend that the salt woman of the Acomas quarreled with the people and left their pueblos. On her way south, she stopped to rest at the present site of the Zuni Lake, where she was turned into the Salt Lake. The Acoma and Zuni Indians made long pilgrimages to gather salt. Of the Acomas, only the men of the Pumpkin and Parrot clans made the solemn journey to gather salt to be distributed to every home on their return. All the prehistoric Basket Makers of the Southwest, dating back to 2,000 B. C., made use of salt, and during the time of the Cliff Dwellers of Mesa Verde and elsewhere, it was pressed by hand into conical shapes, indicating that some ceremony may have been performed in which this product played a major part. Salt was habitually associated with offerings to the Gods by the Greeks, Romans and Semitic peoples. The Gods were worshipped as the beneficient givers of food and "bread and salt go together in common use and as a com-

mon phrase." Since covenants were made over a sacrificial meal, in which salt was a necessary element, "a covenant of salt" is readily understood.

Many expressions, having their origin in ancient times, have arisen because of the great religious and economic significance of salt. The preservative qualities of salt made it a symbol of enduring compact and, therefore, sealed an obligation to fidelity. Such expressions as "there is salt between us," "to eat salt in the palace" and "untrue to salt" were prevalent in ancient eastern countries. Even to-day North Africans and Arabs use the first saying as an expression of friendship. When Christ went up into the mountain he addressed his disciples by saying, "Ye are the salt of the earth," and he warned them that "if the salt has lost its savour, wherewith shall it be salted?" (Matt. 5: 13). Salt which has "lost its savour" is said to refer to an earthy residuum of an impure salt after the sodium chloride was washed out.

References to salt abound in the world's literature. A lecherous or lustful meaning is given the word when Iago refers to Othello "as salt as wolves in pride" (Othello III: 3). Shakespeare refers to salt in such other passages as, "Though we are justices and doctors and churchman, Master Pap, we have some salt of our youth in us" and "I have a salt and sorry rheum offends me" (Merry Wives of Windsor). Chaucer refers to "salt tears." Expressions such as "to pay a salt price," meaning costly or dear; "worth one's salt" or worthy of one's hire; "above or below the salt," indicating social position; "to salt," a plan of deception used in sprinkling mines with ore, or falsifying an invoice, are well known to-day. There was also once the dishonest practise of "salting" or sprinkling the roofs of houses with rock salt to entice the birds of the neighbors. "To salt away" or "salt down" means the preservation of meat, provisions or even money. B. Jonson writes that "his fashion is not to take knowledge of him that is beneath him in clothes. He never drinks below the salt." Such references to the social status of salt have evolved from an ancient custom of masters and servants dining in the same room with the master's table raised on a dais and adorned with a large and imposing salt cellar, while those of lesser social importance sat at tables supplied with salt receptacles to conform to their lower status in life. From this old custom has probably arisen the modern elevated speaker's table.

Salt has also played its rôle in the realm of superstition. It was early used in various rites for the exorcising of evil spirits. The spilling of salt in ancient times was an unlucky omen. In Leonardo da Vinci's famous painting of "The Lord's Supper," Judas Iscariot is indicated by the overturned salt cellar beside his right arm. Captured cities were sowed with salt as a symbol of perpetual desolation. Milan was once razed, burned, strewn with salt and plowed under by Emperor Frederick Barberossa. In Armenia, Russia and Greece, the newborn babies are sometimes rubbed with salt because of its supposed valuable properties in giving strength, vigor and endurance and in preventing corruption. In parts of Germany, salt placed behind the ears of a newborn or in a little package between the folds of the diaper brings sense and protects against evil spirits. In Portugal, after the birth of a baby, the mother and child are protected against evil influences by scattering ground salt on the roof of the dwelling so that the witches may keep busy gathering up the salt and do them no harm. In Flanders, women throw a package of salt behind them so that their confinement may have no evil consequences. In Ireland, salt is hidden in a baby's clothes to protect it against thieving fairies. In America, super-

stitious women throw a few grains of salt over the left shoulder, when any chances to be spilt, to avoid any kind of bad luck.

From the economic standpoint, salt has assumed vast proportions. Since earliest historical times, salt as an article of commerce has been of first importance. Marco Polo speaks of mountains of salt in Taican as follows: "The mountains that you see towards the South are all composed of salt. People from all the countries round, to some thirty days journey, come to fetch this salt which is the best in the world and is so hard that it can only be broken with iron picks. 'Tis in such abundance that it would supply the whole world to the end of time." Among the first roads built to facilitate trade were those to transport salt. The oldest road in Italy is called the Via Salaria or salt road. Salt mines in India have been in use since the time of Alexander the Great. Herodotus writes of the caravan routes to the salt oases of the Libyan Desert. Salt cakes have been used as money in Abyssinia and other parts of Africa and in Tibet. The Roman army was once given an allowance of salt for its officers and men. This salarium was later converted into an allowance of money for salt. From the term salarium comes our very significant word salary. Hence, without salt there could be no salary.

If your ancestors ate salt you are probably fair-skinned; if not you belong to the dark races. This rather astonishing hypothesis has evidently been advanced by some one interested in racial complexions. If you came out of the North, where there was plenty of salt, you are probably white; if from intermediate countries such as China, Korea and India, where salt was not so plentiful, you are probably moderately pigmented; if from the South, where salt was a rarity, you are probably black. The scientific proof of the relationship of racial salt intake to racial color may, in the minds of many, still be lacking, but the doubt does not mar the attraction of the theory.

The therapeutic use of salt has been common in medicine for many years. As a physiologic solution, having the same osmotic tension as the blood plasma, it has been administered intravenously, subcutaneously and by bowel as a standard method of reducing dehydration. It has been used in the treatment of hemorrhage and traumatic shock. In the above, the salt was added to water to make it isotonic and not for any known inherent value possessed by the sodium chloride in the treatment of disease. Only within recent years has therapeutic importance of salt been recognized by clinicians. It has long been known that sodium chloride is reduced in the body in lobar pneumonia, and in recent years it has been used in the treatment of this disease.[1] In 1912, Hartwell and Houget[2] found that they could prolong the life of animals with intestinal obstruction threefold by giving physiologic salt solution. The importance of the salt was not recognized by these authors, and their results were attributed to the relief of dehydration. The importance of salt in body water distribution was dramatically demonstrated by Rowntree[3] when he discovered that he could intoxicate animals and produce convulsions by excessive quantities of water introduced into the stomach. Such intoxications could be relieved or prevented by the use of salt solution. It has been noted that miners, working in high temperature, causing

[1] R. L. Haden, "Relation of Chloride Metabolism to Toxaemia of Lobar Pneumonia," *Jour. Lab. and Clin. Med.*, 10: 337, February, 1925.

[2] J. A. Hartwell and J. P. Houget, "Experimental Intestinal Obstruction in Dogs with Especial Reference to the Cause of Death and the Treatment by Large Amounts of Normal Saline Solution," *Jour. Am. Med. Asn.*, 59; 82, July 13, 1912.

[3] L. G. Rowntree, "Water Balance of Body," *Physiological Rev.*, 2: 116, 1922.

excessive perspiration, frequently have muscle cramps, which become very disabling. This disturbance can be completely relieved if the workmen drink a weak solution of salt water.[4] It is probable that the deprivation of chlorides lessens the gastric secretion and may interfere with digestion.[5] It is well known that a loss of all the gastric juice rapidly results in death.[6] Death can be delayed by administering water and sodium chloride. Persistent vomiting, resulting from experimental pyloric obstruction, will produce profound changes in the blood chemistry and frequently causes tetany.[7] This type of tetany is rapidly relieved by giving sodium chloride to replace the chlorides lost in the gastric juice. The great disturbance in water and chemical balance of the body is strikingly illustrated by the blood studies in acute pyloric, duodenal and small intestine obstructions.[8, 9] There is a marked reduction in chlorides and an increase in the non-protein and urea nitrogens and carbon dioxide combining power. These changes are apparently due to the loss of chlorides and other gastrointestinal juices incident to vomiting. That this is true is evidenced by the fact that the blood changes can be experimentally restored to normal by administering sodium chloride solution.[10] No other known substances will accomplish this restoration. Gamble and Ross[11] have aptly remarked that sodium chloride is the only one of a long list of salts containing both of the ions specifically required for plasma repair. Davidson[12] noted a decrease in the blood chlorides as a result of extensive burns. Other conditions in which a reduction of the blood chlorides has been found are acute peritonitis,[13] toxemia of pregnancy,[14] anaphylactic shock,[15] x-ray intoxication,[16] experimental high jejunostomy[17] and congenital pyloric stenosis.

Experimental work of Mitchell and Carman[18] points to sodium chloride as an important element in general metabolism. They found that rats and chicks grew and developed more rapidly on a

4 E. M. Brockbank, "Miner's Cramps," *Brit. Med. Jour.*, 1: 65, January 12, 1929.

5 R. K. S. Lin and T. G. Ni, "Changes in the Blood Constituents Accompanying Gastric Secretion," *Am. Jour. Physiol.*, 75: 475, 1925.

6 L. R. Dragstedt and J. C. Ellis, "The Fatal Effect of Total Loss of Gastric Juice," *Am. Jour. Physiol.*, 93: 407, 1930.

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8 R. L. Haden and T. G. Orr, "Chemical Changes in the Blood of the Dog after Pyloric Obstruction," *Jour. Exper. Med.*, 37: 377, March, 1923.

9 R. L. Haden and T. G. Orr, "Chemical Changes in the Blood of the Dog after Intestinal Obstruction," *Jour. Exper. Med.*, 37: 365, June, 1925.

10 R. L. Haden and T. G. Orr, "Obstruction of the Jejunum. The Effect of Sodium Chloride on the Chemical Changes in the Blood of the Dog," *Arch. Surg.*, 11: 859, December, 1925.

11 J. L. Gamble and S. G. Ross, "The Factors in the Dehydration Following Pyloric Obstruction," *Jour. Clin. Investigation*, 1: 403, June, 1925.

12 E. C. Davidson, "Sodium Chloride Metabolism in Cutaneous Burns and its Possible Significance for a Rational Therapy," *Arch. Surg.*, 13: 263, August, 1926.

13 T. G. Orr and R. L. Haden, "Chemical Changes in the Blood of the Dog in Experimental Peritonitis," *Jour. Exper. Med.*, 46: 339, September, 1928.

14 R. L. Haden and D. C. Guffey, "Case of Pernicious Vomiting of Pregnancy with Low Blood Chlorides and Marked Response to Sodium Chloride Therapy," *Am. Jour. Obst. and Gynec.*, 8: 486, 1924.

15 R. H. Major, "Studies of Blood Chemistry in Allergy," *Bull. Johns Hopkins Hosp.*, 34: 104, 1923.

16 A. T. Cameron and J. C. McMillan, "Chloride Metabolism in Roentgen Ray Therapy," *Lancet*, 2: 365, 1924.

17 T. G. Orr and R. L. Haden, "High Jejunostomy in Intestinal Obstruction," *Jour. Am. Med. Asn.*, 87: 632, August 28, 1926.

18 H. H. Mitchell and G. G. Carman, "Does Addition of Sodium Chloride Increase Value of Corn Ration for Growing Animals?" *Jour. Biol. Chem.*, 68: 165, April, 1926.

ration of corn to which sodium chloride was added. Older clinicians[19] have reported that deprivation of salt is conducive to low fevers, gangrene of the lungs and intestinal worms. It is related that the ancient laws of Holland prescribed that criminals be kept on bread alone, unmixed with salt, as the severest punishment possible. The dreadful effect was beyond description. The criminals are said to have been devoured by worms engendered in their own stomachs. Salt is very irritating to the intestinal tract if taken by mouth in large quantities and may produce death. Salt was an old remedy for intermittent fever, dyspepsia, dysentery, for the expulsion of worms, application to fetid wounds, to stimulate the appetite and invigorate the system in scrofula, typhoid fever, granular inflammation of the eyes, emetic for poisoning, as a saturated solution rubbed on the chest for fainting and asphyxia, and to control hemoptysis and post-partum hemorrhage. The validity of some of these older claims for salt may, of course, be questioned, since its administration was entirely empirical therapy. That there is a germ of truth presented must be recognized.

There has in recent years developed a renewed interest in the metabolism of salt in the human body. Is its function to maintain proper osmotic pressures in the body; is it responsible in large measures for maintaining water balance; is it the source of the hydrochloric acid of the gastric juice; has it some protective action against certain types of toxemias; does it render the blood tissues more bactericidal; and does it play a rôle in the body growth? These questions naturally arise when a review of the studies of this compound are made. It is doubtful if its action can be fully explained on the basis of physical chemistry. Cushny[20] says that the sodium ion (Na) and the chloride ion (Cl) are both practically inert, except in so far as they change the osmotic pressure. He further states that they are necessary constituents of the body, but their action is limited to the alteration in physical properties of the fluids. Herrick[21] noted a reciprocal relationship between sodium chloride and glucose in the blood. If one of these crystalloids is added to the blood in excess the other promptly decreases, indicating that both function in maintaining osmotic balance. It is generally believed that the chloride ion of the gastric hydrochloric acid has its origin from sodium chloride. Dogs on a strictly salt-free diet will after a time secrete pepsin but no free hydrochloric acid in the stomach. By giving salt, the free hydrochloric acid is restored. Weed and McKibben[22] were able to demonstrate a decrease in the size of the brain by the intravenous injection of strongly hypertonic salt solution. Hughson and Scarff[23] were the first to demonstrate the effect of hypertonic salt solutions on peristalsis. They showed that a strong solution would immediately initiate active peristaltic movements. This work has since been verified and its clinical application demonstrated.[24, 25]

The importance of sodium chloride as a therapeutic agent has been especially

[19] J. D. Palmer, "Sodium Chloride as a Remedial Agent," *Merck's Archives*, 5: 406, December, 1903.

[20] A. R. Cushny, "Pharmacology and Therapeutics," Saunders, Philadelphia, 1911.

[21] W. W. Herrick, "Reciprocal Relationship of Chlorides and Glucose in Blood," *Jour. Lab. and Clin. Med.*, 9: 458, 1924.

[22] L. H. Weed and P. S. McKibben, "Pressure Changes in Cerebro-spinal Fluid Following Intravenous Injection of Solutions of Various Concentrations," *Am. Jour. Physiol.*, 48: 512, May, 1919.

[23] W. Hughson and J. E. Scarff, "The Influence of Intravenous Sodium Chloride on Intestinal Absorption and Peristalsis," *Bull. Johns Hopkins Hosp.*, 35: 197, July, 1924.

[24] H. A. Carlson and O. H. Wangensteen, "Motor Activity of the Distal Bowel in Intestinal Obstruction," *Proc. Soc. Exp. Biol. and Med.*, 27: 676, 1930.

[25] T. G. Orr, P. N. Johnstone and R. L. Haden, "Use of Hypertonic Sodium Chloride Solutions to Stimulate Peristalsis," *Surg., Gynec. and Obst.*, 52: 941, May, 1931.

emphasized in the last few years. The restoration of salt balance by giving physiologic or hypertonic salt solutions in such conditions as intestinal obstruction, pyloric obstruction, peritonitis, duodenal fistula, abdominal distention, and in any condition in which excessive vomiting is a factor, is now recognized as life-saving therapy. The importance of sodium chloride in the treatment of extensive burns has been demonstrated by Davidson. The injection of a small dose of hypertonic salt solution for postoperative gas pains will often bring astonishing results.[26] When chloride is lost as a result of disease its restoration becomes a specific therapy for such disease. This is particularly true in obstructive lesions of the gastrointestinal tract.

Summary

Without sodium chloride there could be no life as we now know it. It has probably been an essential constituent of animal tissue since the beginning of life. Salt has played a very important rôle in the development of the human race from the standpoints of war, commerce, religion and superstition. Its importance in the therapy of many ills is now being recognized and its clinical application common knowledge in medicine. It is maintained in the body at a very constant level and is the most essential factor in controlling the water and chemical balance. The average adult body contains chlorine equivalent to about 300 grams of sodium chloride. It is found in all tissues but more abundantly in the skin, where it seems to be stored for ready use. Osmotic tension and acid-base equilibrium depend upon the salt balance. The average daily intake of salt with the food is 7 to 10 grams, but the adult requirement is only 2 to 3 grams. Normally the kidneys excrete the excess of salt, but in certain diseases of these organs excess of salt tends to increase and maintain oedema. Salt has also been charged with increasing blood pressure in arterial hypertension. For such conditions a reduction of the salt of the diet is indicated. Carl Von Noorden[27] warns that salt reduces the blood's ability to resist disease and points to the difference between the health of the sickly civilized man who uses too much salt and the robust savage who uses but little.

That there could never be a dearth of salt has been shown by some energetic mathematician, who has computed that the world supply is ample for its needs. If the entire ocean were dried up it would yield no less than four and one half million cubic miles of rock salt, or about fourteen and one half times the bulk of the entire continent of Europe above high-water mark.

To treat any disease by restoring to the body that which has been lost as a result of disease is the most rational type of therapy. Salt therapy is usually of this type. Withholding of salt, in certain diseases in which its retention seems too great, is just as rational as supplying a deficiency.

A knowledge of the disturbed metabolism of sodium chloride serves to stimulate our interest in other inorganic compounds of the body in general and forces a realization that such constituents may be of inestimable importance in the study and treatment of disease.

[26] T. G. Orr, "The Treatment of Postoperative Gas Pains," *Ann. Surg.*, 93: 144, July, 1931.

[27] C. Von Noorden, "Why Savages are Healthy," *Abst. in Popular Science Monthly*, p. 68, May, 1931.

SCIENCE SERVICE RADIO TALKS

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RECENT ARCHEOLOGICAL WORK IN THE UNITED STATES[1]

By FRANK M. SETZLER

ASSISTANT CURATOR, DIVISION OF ARCHEOLOGY, U. S. NATIONAL MUSEUM, SMITHSONIAN INSTITUTION

CONVINCING evidence has finally been produced as to the antiquity of man in the New World. A calendar, made up of the annual growth rings in pine trees, extending from the present back to 700 A.D., has enabled specialists to determine actual building dates for hundreds of ancient ruins in Colorado, New Mexico and Arizona. Additional and unsuspected data have been gathered concerning the tribes that inhabited Florida when Ponce de Leon discovered the peninsula in 1513. The mystery and misinformation with which the real American Indian has long been concealed have been measurably lessened. These are some of the important contributions made to the prehistory of our country in the past five years.

Archeology is the study of prehistory. Through archeology we seek to reconstruct living history; to lift the veil of speculation from those diverse peoples who, directly or indirectly, have contributed to our own civilization. Through archeology we endeavor to retrieve the history of peoples who left no written record of their own achievements.

The archeological approach, of course, must lend itself to the particular condition encountered. As Indian tribes differed in language so did they differ in material culture. When the Pilgrim Fathers landed on Plymouth Rock some of the Indians were still living in the Stone Age; some were farmers, dwelling in permanent villages whose very existence depended upon a highly perfected form of communal agriculture; some were hunters who followed the buffalo herds of the Great Plains. It is the story of these divergent Indian peoples, from their arrival in the New World down to the coming of European colonists, that the archeologist seeks to recover and record. Almost from its very beginning in 1846, the Smithsonian Institution has been concerned with this problem of aboriginal discovery and settlement. The earliest migrations of man to this continent; his dispersal and development into numerous Indian tribes; the conquest of his environment and his creation and cultivation of distinctive plants form but a part of the prehistory of the Americas.

Many theories exist in regard to the origin of the American Indian. The one most widely accepted at the present time is that our Indians all belong to the same parent stock, namely, the Mongoloid. This does not imply a direct relationship to the Mongols of the Gobi desert, nor to the Chinese or Japanese. It means merely that the preponderance of evidence points to a common ancestral stock for the American Indian and the Asiatic Mongoloids. The migration of these peoples from Asia across Bering Straits to Alaska, their dispersal throughout North and South America and their numerous distinct civilizations form the most fascinating chapters of American prehistory.

[1] Printed by the courtesy of the Smithsonian Institution.

Within the past five years certain excavations in New Mexico, at Folsom, and in the Guadalupe mountains; Gypsum Cave, Nevada; Nebraska and elsewhere on the western border of the Great Plains, have revealed a peculiar type of flint projectile point associated with the skeletal remains of certain species of animals now extinct in these regions. These biconcave flint points were found with two species of bison—*occidentalis* and *taylori*, the musk-ox, ground sloth and others. Such discoveries have naturally led to speculations among geologists, paleontologists and archeologists as to what geological period, or, if possible, what century before Christ these animals ceased to exist. Of course, all believe that these animals lived during the Pleistocene period, or Ice Age, but since this particular geological period covers many thousands of years, the exact date remains indefinite. The animals may have become obliterated toward the end of the Pleistocene, or at the beginning of the Recent Geological period. The evidence now in hand does not permit a finer time division. The finding, however, by Edgar B. Howard, working for the Philadelphia Academy of Sciences, of characteristic folsom points associated with the horns of a musk-ox in New Mexico would seem to indicate the former presence of a much colder climate than exists at the present time in the Guadalupe Mountains. Thus far no evidence of human skeletal material has been reported associated with these artifacts or the extinct animals. When such human skeletons are found together with these points, it will be of considerable interest to compare them with later Indian types.

To pass from the earliest human remains thus far discovered in North America to those most recently retrieved from the unmeasured past, let us review briefly the results of certain archeological projects recently concluded by the Smithsonian Institution. As aid to the government's Civil Works Administration program to relieve the unemployment situation last winter, the Smithsonian was invited to furnish trained archeologists to supervise archeological excavations in Florida, Georgia, North Carolina, Tennessee and California. This program, one of the most extensive ever attempted at one time in the United States, has resulted in the reconstruction of prehistoric Indian cultures beyond the expectation of American anthropologists.

In Florida, under the direction of M. W. Stirling, chief of the Bureau of American Ethnology, three important sites were excavated. Near Bradenton, on the west coast, a mound revealed the entire floor plan of a temple, giving the first outlines of such a Florida structure. It may have been at such a building that Juan Ortiz was used as a watchman, during his captivity among the Calusa Indians. Ortiz was the Spaniard discovered by De Soto when he landed at Tampa Bay, May 30, 1539. This is the first mound discovered in Florida which contained systematic cremations. In one corner of the temple a double row of posts reenforced the building where the cremations of the bodies took place.

Mounds near Cocoa-Rockledge, on the east coast of Florida, contained bodies of the Surruque Indians, who occupied this part of Florida when it was discovered by the Spaniards. Menendez, the founder of St. Augustine, held a council in 1566 at or near Cape Canaveral which was attended by no less than 1,500 of these Indians. The only knowledge of the Surruque left us by the early explorers of Florida is a brief catalog of repeated disasters, ending with their final extermination slightly more than 100 years after their first contact with Europeans. It was the purpose of the 1934 excavations to supplement these scanty historical records.

A third site, near Belle Glade, Florida, revealed exceptional data requiring

a great deal of further study before any conclusion can be reached regarding the possible relationship of the historic Indians with the ancient remains.

One of the most important sites examined in the Southeast was near the city of Macon, Georgia. Extensive excavations were made in a group of mounds overlooking the Ocmulgee River as well as in others within the city limits of Macon. One of the most interesting discoveries disclosed by the Macon party was a well-prepared clay floor of a circular building. This agrees in most particulars with early descriptions of the covered ceremonial house or "hot house" of the Creeks—such as served the Indians as a combination temple, state house and men's club house. By careful work the floor of this structure was entirely exposed. It consisted of a stiff red clay plaster packed and polished by numerous moccasined feet. In the center was a sunken fireplace and, at equal distances from this, post-holes which marked the former position of the principal roof supports. A most remarkable feature, and one never before observed in ceremonial houses of the southeastern Indians, is the encircling bench on which individual seats were modeled in clay and separated from one another by narrow ridges. Opposite the entrance was revealed the modeled head and body of a great bird, probably an eagle, raised somewhat to serve perhaps as a ceremonial platform. The decoration around the eye of this bird is similar to the conventionalized decoration used on pottery recovered from an old village site near Moundville, Alabama. This would seem to indicate a definite relationship between the Indians in these distant regions.

Near the present city of Murphy, North Carolina, a large mound was excavated which has been identified as marking the ancient town of *Guasili*, visited by Hernando De Soto in 1540. This site, at the junction of Peachtree Creek and the Hiwasee River, was described, at the time of De Soto's visit, as a town of 600 wooden houses—probably an exaggeration—and the capital of a province where the hungry explorers were given a hearty welcome and feasted upon dog meat. They caught and cooked some of the Indian dogs, to the amazement of the natives, who never ate these animals. The red men at once rounded up 300 of the creatures and gave them to the white men to cook. One of De Soto's men wrote: "The lord who bore the name of the province left the capital half a league to meet the Spaniards, accompanied by 500 of the principal persons of the country, very gayly dressed after their fashion. His lodge was upon a mound with a terrace round it, where six men could promenade abreast." This site or mound has been definitely located by Dr. John R. Swanton from its peculiar geographical location and checks with the description given by the early Spanish chroniclers as that of *Guasili*.

Within the Shiloh National Military Park, near Pittsburg Landing, Tennessee, several mounds and the adjacent village sites were excavated. The village site deposits revealed numerous house structures; large quantities of broken pottery vessels were found in the mounds associated with the burials. This famous Civil War battle ground will contribute largely to the reconstruction of the pre-historic Indians who used this beautiful site, located on the east bank of the Tennessee River, long before white men inhabited the region.

On the edge of Buena Vista Lake, eight miles southeast of Taft, California, is the long-abandoned Yokut Indian village of Tulamniu, which has not been occupied since the Spanish explorers visited the site in 1806. Since then the once populous aboriginal settlement has gradually been accumulating an ever-

increasing covering of vegetation and desert sand. It remained for the 200 Civil Works employees to record the history-telling relics of the village and probably solve some of the important questions concerning the aboriginal inhabitants and their mode of living. Various burial sites of the Yokut Indians were discovered. They were buried in a not particularly careful manner, but a stout post was placed beside each grave. The remnants of these posts may enable archeologists to establish a definite chronology for the region, thus turning prehistory into dated history for California. The cedar posts have the annual growth rings well preserved. It is hoped to learn, by comparing these rings with the long calendar of annual tree rings shown in the California redwood trees, the years when the grave posts were cut and placed as markers for the individual graves. By a similar calendar of tree rings recovered from numerous remains in the Southwest, an unbroken sequence from the sixth century A. D. to the present has been worked out.

Even though the material obtained from the ruins in the United States consists of non-perishable objects—except in dry caves and desert regions—the science of archeology has been able to develop certain techniques which will enable archeologists to determine definite criteria which can be used for establishing relationships between the Indian cultures in the various areas. Very little of the perishable material culture, such as wood, feathers, skins, cloth, etc., has been preserved, but by the excavation of historically known or documentary sites, we can obtain the essential archeological pages leading back into the dim or protohistoric period, and then on into the dark or prehistoric. Archeology, combined with the study of the skeletal material—physical anthropology—and the study of the living Indian groups—ethnology, hopes to reconstruct the unbiased history of the United States before Columbus.

HUNTING EARTHQUAKES

By Rev. JOSEPH LYNCH, S.J.
DIRECTOR, SEISMIC OBSERVATORY, FORDHAM UNIVERSITY

A LADY leaving a theater after a popular lecture on astronomy was overheard to exclaim to her companion, "But the most marvelous part of astronomy to my mind is how they were ever able to find out the names of all the stars." To many people it seems equally marvelous that at an earthquake observatory we are able to locate an earthquake almost as soon as it occurs. Yet in reality the location of an earthquake at an earthquake observatory is no more marvelous than the discovery of the name of a star by the one who gave it that name. The location of earthquakes at an observatory is like the water falling over Niagara—it can't be helped!

Some time ago, we read of the unfortunate sinking of the Nantucket Lightship by the White Star Liner *Olympic*. The *Olympic* was being guided to the lightship by radio waves. Nowadays, a ship can be quite definitely located by radio shore stations if she continuously sends out radio signals as the *Nantucket* was doing. In a similar way an earthquake can be located by earthquake observatories by the waves it sends out. The earthquake corresponds to the ship at sea constantly transmitting waves. The observatories correspond to the shore stations which pick up these waves and from their intensity and direction instantly locate the quake.

An earthquake is a sudden shifting of a part of the earth's crust. This shifting may take place near the surface or it may take place a hundred miles or more down in the crust. But wherever it takes place, it jars the nerves of mother earth and sends a quiver throughout her system as a blast in a stone quarry causes the ground in the neighborhood to quiver. This quivering of the earth might be likened to the quivers or ripples on the surface of a pond when a pebble has disturbed its waters. The quivers travel throughout the entire earth as the ripples travel over the entire surface of the pond.

How can these quivers be detected? They are too small to be seen and too feeble to be felt by the unaided senses. The seismograph is the instrument designed to detect and magnify these quivers. Its principle is very simple. If an ordinary playing card be balanced on the tip of the middle finger and a penny placed on top of the card, the card, without any practise, can be flicked away, leaving the penny on the finger. The card must be flicked quickly. The penny stays on the finger because of its inertia—a Latin name for laziness. It refuses to be hurried away as the card was and it stays there. When an automobile starts up suddenly, the passengers lurch backward because of their inertia—they refuse to be hurried and the car starts off momentarily without them so that they lurch backwards in the car. Actually, they stay still while the car moves from under them as the penny stays still while the card moves from under it. When the brakes of a car in motion are jammed on suddenly, the passengers lurch forward because of their inertia. In this case, they refuse to have their motion stopped so that when the car stops they continue forward. All bodies possess this inertia, and the heavier a body is the more inertia it possesses.

Inertia shows itself as a resistance to motion. If a body is at rest it wants to stay at rest. If a body is in motion, it wants to stay in motion. We hate to go to bed, but when we are there, we want to stay there. This is the principle of the seismograph—because of its inertia it stays still while the ground underneath it moves. A seismograph is a pendulum with its tip resting gently on the ground. When the ground underneath the pendulum quivers, as it does in an earthquake, the pendulum, because of its inertia, refuses to quiver so that if the ground moves slightly towards the right, the pendulum stays still and relative to the earth appears to move to the left. If the tip of the pendulum be resting in loose sand, the relative motion of pendulum and earth will be traced out in the sand. This was the arrangement in the early types of seismographs. An ordinary pendulum was suspended so as to have its tip resting in loose sand on the ground—the motion of the ground would then be traced out by the pendulum in the sand. As each new quiver was traced out, the figure on the ground became very complicated. To avoid this complication the next improvement was to have the tip of the pendulum resting not on the ground directly, but on a sheet of paper covered with lampblack. This paper was wound on a drum which was kept revolving by clockwork under the pendulum. With the ground at rest the tip of the pendulum would scratch out a white line in the lampblack on the paper as the drum moves continually forward under the pendulum. If the earth quivered, *i.e.*, if an earthquake occurred, the drum, since it is attached to the earth, would also quiver and this quiver would be traced out in the lampblack as a sideways motion due to the sideways motion of the drum under the tip of the pendulum. The pendulum is so suspended that it can only move from side to side in one

plane. If two such pendula be placed, one facing north and south and the other east and west, they will between them pick up any quiver from whatever direction it may come.

The motion of such a simple pendulum will, of course, be very slight—particularly if it is some distance from the scene of the quake. To magnify the motion so as to make it more visible, several devices have been introduced. In one instrument, the tip of the pendulum, instead of resting on the smoked paper directly, is attached to the short arm of a lever—the tip of the long arm resting on the smoked paper and acting as the pen. Other and better instruments do away with the smoked paper altogether and substitute for it sensitized photographic paper. The pen in this case is a tiny beam of light reflected from a mirror attached to the end of the pendulum—a motion of the mirror causing a motion of the beam of light over the photographic paper. This optical lever is a big improvement over the mechanical lever previously mentioned. The most sensitive types of seismographs have a coil attached to the end of the pendulum. Two powerful magnets are set up on either side of the coil and each quiver of the coil in this magnetic field generates a current which moves the mirror of a galvanometer, the mirror in turn reflecting a light spot back and forth across the photographic paper to give us our record of the earth's motion magnified about 2,000 times.

When an earthquake occurs, then the whole earth quivers and this quivering can be detected by seismographs, utilizing the principle of inertia. But how can we tell from a record of this quivering just where the earth did quake?

When the earth quakes, it sends throughout the earth two distinct kinds of quiver—two distinct kinds of ripples which travel at different rates. Just as in a thunder storm at each lightning discharge we both see the lightning and hear the thunder because both a light wave and a sound wave are sent out from the disturbance in the clouds, so in an earthquake two distinct kinds of waves are sent out—one pushing or compressing the earth ahead of it and hence called a compressional wave, and the other shaking the earth from side to side as it travels and hence called a transverse wave. Like the thunder and the lightning waves, these two earthquake waves travel at different rates—about five and three miles per second, respectively. For every second we can count between the thunder and lightning waves, the distance of the thunderbolt is one fifth of a mile from the observer, so for every second we can count between the compressional and transverse waves of an earthquake, the quake is a corresponding distance away—for instance, in the last Utah quake of March 12, the number of seconds counted at Fordham between the two quake waves was 293, amounting to a distance of 1,940 miles. The seismograph records the arrival of these waves, and the exact second at which each arrives is told by time marks placed automatically on the record by an accurate clock.

So much, then, for the distance of a quake from a given observatory, determined by the number of seconds elapsing between the arrival of the compressional and transverse earthquake waves. But how is the direction determined? If we have three stations in communication, the matter is simple. If we describe three circles on a globe with each of the three stations as centers and the distances of the quakes from the respective stations as radii, the three circles can only intersect at one point and that point is the center of the quake. With sufficient instruments we can locate the position of the quake from the records of a single station, but the description of such a method is beyond the scope of so short a talk.

In conclusion, just a word on the

practical side of earthquake study. One of the most important aims of seismology is the protection against earthquakes by proper building construction and proper and adequate insurance. Very careful study of the findings of seismology has been made by the Board of Fire Underwriters of the Pacific. A staff of qualified engineers has been maintained by them in the Los Angeles and San Francisco regions, studying the effects of earthquakes on buildings there, and their findings have resulted in considerable improvement in the building codes and in adequate insurance against earthquake loss. We always will have earthquakes, but they can be efficiently prepared for and adequately insured against at a reasonable cost, and the efforts of the Board of Underwriters of the Pacific in this connection deserve more than a word of thanks and praise.

HEALTH AND THE DEPRESSION

By G. ST. J. PERROTT

CONSULTANT, U. S. PUBLIC HEALTH SERVICE; RESEARCH ASSOCIATE, MILBANK MEMORIAL FUND

ONE of America's greatest resources is the health and vitality of its people. Health outranks in importance our natural resources of coal and iron and forests. It is infinitely more precious than our gold and silver, our bank deposits or all the output of our factories. In the past, our energy and health made us the great nation that we are to-day. Has the health of the people of the country been damaged by the economic depression? Is sickness prevalent among the unemployed and their families? Are the sick receiving adequate medical care? Are the "depression poor" getting enough food and a balanced diet? Are we bringing up a crop of malnourished children to be the victims of tuberculosis in later years? These are fair questions, important questions—but we are only beginning to answer them. For while we gathered voluminous statistics on mineral reserves, bank deposits and factory production, we know little about the health of the people as a whole except what we could surmise from the number of persons dying each year.

When the economic depression reduced the standards of living of millions of Americans to a bare subsistence level, when many had inadequate food and clothing and shelter, and were forced to look to public charity for support, misgivings arose as to the effect of these conditions on health. But when the death rate was examined, it was found that fewer people were dying in these depressed times than had died during the preceding prosperity. Each year from 1929 to 1933, the deaths from all causes (including deaths of infants and deaths from tuberculosis) declined, until in 1933 the death rate had reached the lowest figure on record. This led optimists to speculate as to the possible advantages of the depression from a health standpoint. They talked of the desirability of "tightening the belt during hard times" and "living the simple life." Others felt that any ill effects of the depression would not be reflected immediately in an increased death rate, and furthermore that serious damage to the health of the people had been prevented by a very effective program of public health and social relief. Their chief concern was lest this relief work be discontinued before the economic emergency was over.

Surgeon-General Hugh S. Cumming, of the U. S. Public Health Service, recognized the need of obtaining additional

first-hand information on the health of unemployed workers and their families. So, early in 1933, he directed that a house-to-house health canvass be made in a number of large cities for the purpose of finding the nature and extent of illness in families of wage-earners that had been hard hit by the depression, and of comparing their health with that of more fortunate families where the wage-earner had kept his job throughout the depression. Districts were selected in the poorer sections of the cities but not in strictly slum areas. A record was obtained of the illnesses of each member of the family for the three months before the visit, together with the medical care received by any sick member of the household and whether it was paid for or obtained free. In addition, the income of each wage-earner was recorded for each year from 1929 to 1932. For a selected group of 1,200 families, information on the daily diet was obtained in order to judge if the food were adequate to maintain health. Physical examinations of school children in the surveyed families in two localities were made to determine the extent of malnutrition. During the course of the study, visits were made to the homes of some 12,000 families in ten cities by investigators from the Public Health Service and the Milbank Memorial Fund.

The incomes of these families show that their standard of living must have been very low. It was found that 75 per cent., or 9,000 families, had incomes of less than $1,200 in 1932, and 40 per cent. of them had incomes of less than $600 that year. In 1929, on the other hand, three fourths of these people had been in reasonably comfortable circumstances. On the day of the visit in 1933, one fifth of all the families were depending on public relief and many others had no means of support.

When the illness records of these people were studied, the highly significant fact was found that health had suffered most in families hardest hit by the depression. The illness rate was more than 60 per cent. higher in these families than it was among their more fortunate neighbors who had suffered no drop in income. Sickness among these "new poor" was more prevalent than among the "chronic poor" who had been poverty stricken even in 1929, a fact which suggests that ill health is in some way associated with sudden change in the standard of living. The direct effect of unemployment is suggested by the fact that the sickness rate in families having no employed workers was 66 per cent. higher than that in families with full-time workers and 27 per cent. higher than that of families with part-time workers only. These higher illness rates appeared among the children as well as among the adults. Malnutrition among children in families suffering the greatest drop in income was found to be nearly twice as high as in families in comfortable circumstances in 1933. Children in families without social relief were found to have a higher rate of malnutrition than similar families aided by relief.

The diets of these families reduced to poverty during the depression had suffered along with their incomes. Diets were particularly deficient in the protective foods—milk, citrus fruits and fresh vegetables. These foods were considered luxuries, and low-priced bulky and filling foods, such as beans and macaroni, were substituted. The deficiency in the diets of the new poor may well have contributed to their increased sickness.

The general conclusion from this survey of 12,000 families is that the highest incidence of disabling illness appeared in the group that suffered the greatest loss of income during the depression. This was true of each city separately as well as for the group as a whole. If these findings are representative of the country, why has not the gross death

rate increased? Why have infant and tuberculosis mortality, in general, continued to decline?

A final answer to these questions can not be given. Certainly the low death rate for the country as a whole is encouraging evidence that the economic depression has not killed very many of the American people. However, this indication should be accepted only in so far as it really is a sign of good health. The death rate is not an adequate criterion of the extent of sickness. It is not affected immediately by unfavorable living conditions unless starvation and pestilence are actually present. It does not promptly measure decreased resistance to disease. It is not an accurate measure, for example, of malnutrition. The human animal is hard to kill, and will take much punishment before actually dying. We now have a higher standard of health than one which is concerned merely with warding off death. The average American wants to be alive and well, not merely alive. If he is not well, he wants adequate medical care to make him well.

As we have seen, there are indications that while the average American is alive, he is not always as well as he should be. Sickness rates have apparently risen among the unemployed population, especially in those instances where social relief has been unequal to the situation. Signs of an increase in the number of cases of mental disease are not lacking. Malnutrition among school children has increased in some localities. Higher infant and tuberculosis mortality have been experienced in certain areas of New York City where unemployment was most serious. The urban death rate for the country has been on a higher level for the first six months of 1934 than for the corresponding period in 1933. Thus the health picture may not be as rosy as it has been painted.

Conditions would probably be much worse to-day were it not for the untiring efforts of the medical profession and public health and relief organizations. While the new poor in the surveyed families received considerably less doctor's care than that to which they had been accustomed in better times, the physicians of the country responded generously to the needs of these people. The doctor received no remuneration for over 50 per cent. of the visits made to this group. The hospitals also gave a tremendous amount of free care—85 per cent. of all hospital care to these families was free. This unselfish service, together with the care provided by public and private relief agencies, has probably prevented what might have been more serious results of the depression had illnesses gone entirely unattended.

While we can justly congratulate ourselves on past accomplishments, even more must be done in the future. The indication of increased illness among the unemployed may not indicate a serious condition now, but it does point a warning finger ahead. It must be recognized that, in addition to life, liberty and the pursuit of happiness, health is an inalienable right of the American people. Medical care is a necessity of life, as well as food, clothing and shelter. These necessities must be made available to all if the health and efficiency of the wage-earning population are to be maintained. We may not yet have felt the full effect of the depression on our health and vitality. Every effort must be made to preserve this great national resource.

THE GREATEST FACTORY IN THE WORLD

By Dr. GEORGE J. PEIRCE

PROFESSOR OF BOTANY, EMERITUS, STANFORD UNIVERSITY

PERHAPS I should justify at once the high-sounding title of this discourse, and I am glad to do so. Every pound of food, every particle of clothing, most of our houses, many of our implements, most of our luxuries, are the products of this factory. It has no subsidiaries, but it has units all over the world. Most of them operate only seasonally, some of them throughout the year; but their working day is as strictly limited as if by code or by union. The factory is the green leaves of plants.

If we undertake to state the total value of the food products alone we have to consider very large figures. The annual production of human food in the United States of America is valued at approximately fifteen billions of dollars ($15,000,000,000). The value of food produced for human consumption, but devoured before or after harvest by other animals, may be estimated at one quarter of this sum. The value of what might have become food for these predatory animals and for man, but consumed by parasites living on the food plants, may be estimated at one eighth of this sum. We may set the year's potential production of the United States at twenty billions of dollars worth of food. Because we can not appraise in dollars what nourishes the birds of the air, the beasts of the field, the wild animals of the woods and the creatures inhabiting the waters, we can form only a vague idea of the magnitude of the yearly yield. The quantity is stupendous, the value can not be stated in the terms of any currency. When we consider the secondary products, the cotton, wool, silk, of our clothing, the hides and skins in our shoes and gloves, the woods of our houses and furniture, the handles at least of many of our tools, the cases and cabinets of our pianos and radios, and add those values to that of the forests and jungles which are the homes of other men and of other animals, and from which we derive rubber, quinine and many other industrial and drug materials, we can imagine no measure of value. We may go back to an old expression, "Green plants stand between the animal world and starvation," but this gives us an idea of the importance, though not of the value, of the factory.

There is no general store of food in nature. In the earth's crust are accumulations of oil, coal, gas, iron, gold—the products of ages past. Here and there are bodies of fresh and of salt water. Man's need of materials for implements and fuel are supplied from these stores. But there is no accumulation of food, or of any raw material from which man knows how to make food. It is made annually, for the most part seasonally, in the hours between sunrise and sunset, whenever and wherever there are warmth enough and water enough. Because the production of food is periodic, with no considerable store anywhere, the world's margin of safety against starvation is at all times narrow. All concentrations of population into cities, towns, islands, ships, etc., involve the hazard of starvation, partial or complete. Under the conditions of our civilization the production and the consumption of foods may be widely separated, and in all cases most of the food made is consumed outside the factory.

The factory is the world of green about us, the green leaves of the fields,

the orchards and the gardens, the forests of the land, the seaweeds which clothe our rocky coasts and float in the oceans, those smaller weeds which infest our swimming pools and reservoirs, obstruct our irrigation ditches and may even constrict our streams and interfere with navigation. The leaves of land plants are ordinarily green in appearance. In autumn they may change to reds and yellows, in summer and in spring their greenness may be overlaid and obscured by red or yellow pigments, and parts may be blanched or empty, showing yellow or white. The seaweeds may be red or brown or green, but in every case green is the underlying color. Why this greenness? Just as furnace, engine, dynamo and motor are essential parts of any other factory, delivering the energy for operation, so the green color of plants delivers the energy required and used in the manufacture of food. This color is contained only in the living parts of plants. It is made by the living cells, it absorbs energy for the living cells, and this energy is used by the living cells in converting the raw materials into foods. The green color is a screen capturing energy. Like the photographic film or plate, the receiver of a telephone or the antenna of a radio, the green color of leaves intercepts and absorbs energy. The energy is used, applied and consumed in making foods from raw materials as coal is consumed in making cloth from fiber. The energy is sunlight. The quantity and quality of sunlight reaching the green leaves of plants varies with the length of day, the altitude, the exposure and the quality of the air. The dry clear air of the desert and the sparkling dustless air of the Sierra Nevada permit a larger fraction of total daylight, and especially a larger fraction of the violet and ultraviolet portions of the sunlight, to reach the surface than can pass through the high fog of our coast counties or the high humidity of the Atlantic seaboard. But of the sunlight falling upon the surface of a leaf only a part is absorbed, the rest being reflected or transmitted. If all the sunlight were absorbed leaves would look black. Only a part of the sunlight is absorbed and the rest escapes, giving us the impression of greenness. What is absorbed consists of radiant energy of certain wave-lengths, mainly red rays and blue rays. These rays are used to do the work of converting food materials into foods, raw materials into finished products.

The different shapes, sizes and positions of the leaves and other green parts of plants, in the sea and on the land, are primarily determined by the need of energy, the means of absorbing it; but protection against drying, protection against destruction by wind, rain and enemies, these also must be provided. The shape, size, texture, therefore, of every leaf represent the adjustment which the growing leaf made to all these influences, just as a boy grows to shape, size and color determined by his parentage and circumstances. The structure of the greatest factory in the world, the green parts of plants, is no less perfectly fitted for the intake of raw materials and the elimination of waste. Examination of the ground plan and elevation of such a factory discloses unnumbered green cells with air spaces between, forming a fairly compact palisade in the upper third and a loose sponge in the lower two thirds of the thickness of the ordinary horizontal leaf. Through the so-called breathing pores on the surface air passes freely, inward and outward, into and out of these air-spaces whenever the pores are open; and through a system of tubes, which also form the framework of the leaf, water moves from the roots and stems into the leaf and back again to stems and roots; water, carrying dissolved raw material, and dissolved foods, according to the direction of the current: intake and export, from air and soil to the factory,

from the factory to the growing or working or storing tissues, as the case may be.

The raw materials for this factory come from air and soil, the wastes return to air and soil, the finished products remain in the body of the plant. The raw materials are of three sorts, all very simple, all very stable, all very common and all readily dissolving in water. Some of them are solids—the soil substances; one is a liquid—namely, water; the third is a gas—the carbon dioxide of the air. This last is formed by human beings and almost all other living things, and given off to the air. It is formed when coal, wood, gas, gasoline, oil and many other substances are burned. Great quantities of it are formed in times of forest fire, and it escapes with other hot gases from the vents of active volcanoes. Nevertheless, although the quantity of carbon dioxide gas in the air is enormous, the dilution is strikingly great. Two hundredths of one per cent. is the usual proportion. Yet because it is a gas, and in gases which we call the air, it moves with such ease, freedom and speed that it is never exhausted in any one spot, no matter how rapid the absorption. It is unlike water in this respect, for water may be taken in or be needed by a plant faster than it can be provided. Hence frequent rain or irrigation is needed to maintain an adequate supply. And the solids are still slower. They move only in solution in the soil water or as they may be moved by washing. The solids, the plant foods, as the agriculturist calls them, or the food materials, as the botanist calls them, are the nitrates, phosphates, sulfates and chlorides which make up such a large part and the most valuable part of the soil. These furnish the nitrogen, sulfur, phosphorus, the iron, potassium, calcium and magnesium which are such important elements in our diet.

We have thus formed some idea of the factory in which all our food is manufactured—the green leaf; the energy with which it operates—the sunlight; the raw materials which it uses—carbon dioxide from the air, water from the soil, certain substances called salts which the soil water takes up, dissolves, from the soil.

Every day when it is warm enough and wet enough and light enough foods are made in green plants. These foods are sugars, starches, fats and oils and more complex substances called proteins. The first and simplest of these are sugars. All the rest are derived from them by subtraction or addition or rearrangement of atoms in the molecules. The combination of carbon dioxide and water into sugar is the most important chemical process in nature, for upon it depends the existence of the world of living things, of ourselves and of all the other animals and the plants. Applying energy which comes in the form of light from the sun to carbon dioxide and water, living cells manufacture in the hours of daylight the most valuable and one of the most common substances in nature. The process goes on daily. We see no smoke or dust, we hear no noise, we see and smell and taste no wastes from this factory. On the contrary, it purifies the air and returns to it one of its most valuable ingredients, oxygen.

How this combination is effected remains the business secret of the greatest factory in the world. In spite of the most careful, persistent and ingenious study of botanists, chemists and physiologists, the details of manufacture are unknown. The factory is known, the raw materials are known, and the energy; the products are priceless and indispensable; the process remains unknown.

In spite of this fundamental ignorance, botanists have enormously improved and increased the products; they have protected the factory from injury by parasites; they have protected

it from interference by soil and air pollutions, from poisonous gases, from the dusts thrown out by some of man's factories; they have made the production of food and its derivatives of all sorts more secure, more suitable for human needs, more abundant and cheaper. It remains for men in other fields to improve the means of distribution, so that each and all may have due share of the products of the greatest factory in the world.

DO SNAKES HAVE LEGS?

By Dr. BERT CUNNINGHAM
PROFESSOR OF BIOLOGY, DUKE UNIVERSITY

From time to time one hears of snakes that are said to have legs; in some of the cases the legs are visible under all circumstances, while in others they become visible only under some special circumstances, as for example when a snake is run over by an automobile or when a specimen is tossed into a fire.

It is commonly known that there are legless lizards that have bodies quite similar to snakes, so much so in fact that they are often mistaken for snakes. It is perhaps less well known that there are other lizards which have very small legs and exceedingly long snake-like bodies. Such a specimen is shown in Fig. 1. Doubtless upon superficial examination, one unacquainted with the technical differences between lizards and snakes might well call this a snake with legs. It has, however, several characteristics which separate it from serpents, namely, movable eyelids and external tympanic membranes which any one may easily observe; besides, there are certain internal structures, such as the shoulder girdles, which are never to be found in serpents, and the manner of hinging the jaw, which is entirely different from that of snakes.

In other snake-like lizards the posterior legs have disappeared and only small fore legs are present. This type is shown in Fig. 2. In still others the fore legs have disappeared and the hind legs have become flap-like (see Fig. 3) structures, bearing but little resemblance to legs. Still others have entirely lost both pairs of legs, and also have become so highly modified internally that it takes a herpetologist to separate them from snakes.

With such specimens as these possible and considering the superficial knowledge of the average person, one would not be at all surprised to hear reports of snakes with legs, the same being not snakes but lizards with slightly developed legs.

The explanation of the protrusion of legs when a serpent is crushed or thrown into the fire is as simple as the foregoing. For many years I have heard of snakes extending their legs when thrown in the fire, as well as under other circumstances. The story to the herpetologist is old and threadbare, but not so to the average citizen. For years I had hoped to examine at first hand one of these specimens. Finally the opportunity came. The case was reported in the newspapers, and I secured the specimen, a spreading adder. The animal with the distended "legs" is shown in Fig. 4. An x-ray of this specimen is shown in Fig. 5. At first glance the right and left structures are different, the right being more compact and appearing to have strips of bone within it. Figs. 6 and 7 show a similar condition observed in another species, while Figs. 8 and 9 show the condition in another specimen of the spreading adder, which was kindly loaned to me by the zoological museum of the University of Michigan. In none of these specimens is there a hint of any


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FIG. 8.—Rudimentary or vestigial hind-limbs of Python, as exhibited in the skeleton and on the external surface of the animal. Drawn from nature, ½ nat. size (Zoological Gardens).

bone structure similar to those of a leg, and in none of them is there any evidence of any bones similar to the pelvic girdle. This leads me to say what every herpetologist knows, that these structures so often called "legs" are but the copulatory organs (hemipenes) of the snake, which are extruded through the cloacal opening.

But the ancestors of snakes did have legs (be ye naturalist or fundamentalist), and there are some species still in existence which bear the marks of their ancestry. These have short spurs on the outside connected with bones running lengthwise of the body, such as are shown in Fig. 10. This condition is to be found in the python and some of its relatives.

It was our good fortune to be able to secure a specimen of *Constrictor orphius* from the West Indies, also loaned us by the University of Michigan, for photographic and x-ray purposes. A ventral view showing the spur is shown in Fig. 11, while Fig. 12, an x-ray, shows the internal relation of this structure to the long bones within the body. The spurs are thought to aid in climbing, and some look upon them as vestigial hind limbs.

Since there are snakes with structures so nearly like "legs" and since it is assumed with good reason that the ancestors of snakes were legged animals, one should not be surprised if occasionally, perhaps extremely rarely, one should find a serpent with structures which, while anomalous, resemble legs. Such an instance was reported to the Société de Biologie in 1902 by Launoy.[1] Concerning the specimen he says: "At the level of the anus, laterally and symmetrically placed one may see two well-developed buds of unequal proportions and form. One is enlarged distally and attached to the body by a peduncle; the outer end is divided into two distinct digits which are without nails. There was no evidence of a pelvic girdle." Histological examination did not reveal any bony tissue in these structures. Whether these structures may be called legs or not, the author (Launoy) evidently thought they were and so expressed himself in the title of the paper.

When one is asked, therefore, if snakes have legs, the answer is that of the politician, "Well, sometimes yes and then again no," and again, "It depends upon your definition of snake and leg"; but if the question be restricted to our common North American snakes and to real legs the answer is most surely no—the structures so often thought to be legs are nothing more than hemipenes or copulatory organs. But that does not necessarily mean that no one shall ever find a snake with legs.

[1] "Embryon de vipère bipède et cyclocephale," *Comptes Rendus Soc. Biol.*, 54: 449–50.

"SNAKES" WITH "LEGS"

Fig. 1. A snake-like lizard, the three-toed seps, which has four very much reduced legs. Photographic copy, Harmsworth Natural History. Fig. 2. A snake-like lizard, the Mexican amphisbaena, in which the posterior legs have completely disappeared. Source same as above. Fig. 3. A snake-like lizard, scale-footed lizard, the fore legs of which have disappeared, and the hind limbs are scaly paddles. Source same as above. Fig. 4. Spreading adder, *Heterodon contortrix* (Linné) showing structures said to be "legs" in newspaper reports. Fig. 5. X-ray photograph of above specimen. Fig. 6. Ventral view of *Farancia abacura* Holbrook, showing protrusion of hemipenes. Fig. 7. X-ray photograph of above specimen—(specimen secured through the courtesy of the "Bug-House Laboratory"). Fig. 8. Another specimen of the spreading adder. Fig. 9. X-ray of the above specimen. Fig. 10. Photographic copy of python "spurs" and vestigial bones, from Romanes. Figs. 11, a, b, c. "Spurs" of snakes of the python type. Fig. 12. X-ray of *Constrictor orphius* showing the relation of vestigial bones and spurs. All x-rays were made through the courtesy of Dr. Reeves, of Duke University Hospital.

SIR JAMES JEANS

THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT ABERDEEN

Early in September, for the third time during its one hundred and three years of existence, the British Association for the Advancement of Science convened in Aberdeen. On the occasion of its first visit three quarters of a century ago, His Royal Highness the Prince Consort was president of the association and delivered the inaugural address. To mark the occasion the following message was conveyed to the King:

Your Majesty,—We, the members of the British Association for the Advancement of Science assembled in the City of Aberdeen in annual session, desire humbly to recall to Your Majesty that it was in this City that His Royal Highness The Prince Consort assumed the Presidency of the Association in the year 1859. From the Presidential Chair, he conveyed to the assembled members of the Association a gracious message from Her Majesty Queen Victoria, and delivered an address which disclosed his own profound interest in the advancement of Science. The many marks of Royal favour which have been extended to our Association on subsequent occasions have provided further signal encouragement to us in our pursuit of the aims defined by His Royal Highness, and on all these counts we now desire to express to Your Majesty our humble gratitude. J. H. Jeans, *President*.

The following reply was received from Sir Clive Wigram:

I am commanded by the King to thank the members of the British Association for the Advancement of Science for the loyal message which they have addressed to His Majesty, their patron, from the Inaugural General Meeting in the Ancient City of Aberdeen. His Majesty appreciates their kind remembrance of the occasion when the Prince Consort, as President of the Association, delivered a message from Queen Victoria to the members assembled in this City three quarters of a century ago. The King desires me to assure the members of his unabated interest in their meetings and his confidence that their investigations into the manifold problems confronting present day scientists will continue to be productive of results which will benefit mankind.

Over two thousand scientific men and women of Great Britain—together with workers of many countries—assembled under the presidency of Sir James H. Jeans in the Capital buildings of Aberdeen. Not for fifty years had the presidential chair been occupied by a theoretical physicist, and Sir James remarked that "in the interval the main edifice of science had grown almost beyond recognition, increasing in extent, dignity and beauty. Yet the theoretical physicist must admit his own department looks like nothing so much as a building which has been brought down in ruins by a succession of earthquake shocks," because it had been built on the "ever-shifting sands of conjecture."

Sir James continued his discourse on "The New World-Picture of Modern Physics" and in conclusion considered the topic of science and unemployment discussed in the April number of The Scientific Monthly by Drs. Millikan, Jewett, Coolidge and Karl T. Compton. It is thus of especial interest to note the last paragraphs of his address:

This last brings us to the thorny problem of economic depression and unemployment. No doubt a large part of this results from the war, national rivalries, tariff barriers and various causes which have nothing to do with science, but a residue must be traced to scientific research; this produces labor-saving devices which in times of depression are only too likely to be welcomed as wage-saving devices and to put men out of work. The scientific Robot in *Punch's* cartoon boasted that he could do the work of 100 men, but gave no answer to the question—"Who will find work for the displaced 99?" He might, I think, have answered—"The pure scientist, in part at least." For scientific research has two products of industrial importance—the labor-saving inventions which displace labor, and the more fun-

damental discoveries which originate as pure science, but may ultimately lead to new trades and new popular demands providing employment for vast armies of labor.

Both are rich gifts from science to the community. The labor-saving devices lead to emancipation from soul-destroying toil and routine work, to greater leisure and better opportunities for its enjoyment. The new inventions add to the comfort and pleasure, health and wealth of the community. If a perfect balance could be maintained between the two, there would be employment for all, with a continual increase in the comfort and dignity of life. But, as I see it, troubles are bound to arise if the balance is not maintained, and a steady flow of labor-saving devices with no accompanying steady flow of new industries to absorb the labor they displace, can not but lead to unemployment and chaos in the field of labor. At present we have a want of balance resulting in unemployment, so that our great need at the moment is for industry-making discoveries. Let us remember Faraday's electromagnetic induction, Maxwell's Hertzian waves and the Otto cycle—each of which has provided employment for millions of men. And, although it is an old story, let us also remember that the economic value of the work of one scientist alone, Edison, has been estimated at three thousand million pounds.

Unhappily, no amount of planning can arrange a perfect balance. For as the wind bloweth where it listeth, so no one can control the direction in which science will advance; the investigator in pure science does not know himself whether his researches will result in a mere labor-saving device or a new industry. He only knows that if all science were throttled down, neither would result; the community would become crystalized in its present state, with nothing to do but watch its population increase, and shiver as it waited for the famine, pestilence or war which must inevitably come to restore the balance between food and mouths, land and population.

Is it not better to press on in our efforts to secure more wealth and leisure and dignity of life for our own and future generations, even though we risk a glorious failure, rather than accept inglorious failure by perpetuating our present conditions, in which these advantages are the exception rather than the rule? Shall we not risk the fate of that over-ambitious scientist Icarus, rather than resign ourselves without an effort to the fate which has befallen the bees and ants? Such are the questions I would put to those who maintain that science is harmful to the race.

Sir James paid tribute to the late Sir William Hardy, owing to whose death he was in the presidential chair. The Hardy Memorial Lecture, delivered by Sir Frank Smith, constituted the first of the two customary evening discourses. He spoke on the preservation of meat, fish and fruit, a problem to which Hardy had devoted most of his life. The other discourse was given by Professor W. L. Bragg, who discussed "The Exploration of the Mineral World by X-rays."

Membership for the Aberdeen meeting reached a total of 2,784. The sectional meetings as well as the more general part of the program were unusually well attended, and it was agreed that the association had fulfilled the mandate laid down at the first meeting in York in 1831 to promote and direct the course of science, to foster intercourse among scientific men and to obtain more general attention for the objects of science from those not trained in science. The objects of the association were carried out in part by its extensive program of general and sectional excursions—features emphasized to a much greater extent at scientific gatherings abroad than in America.

THE DEDICATION OF THE LILLY RESEARCH LABORATORY

PHARMACY WEEK in 1934 will go on record for at least two notable occurrences, for it marks the week and the year when the American Institute of Pharmacy was dedicated at Washington, D. C., and the formal opening of the new Lilly Research Laboratories in Indianapolis on October 11. The exercises were attended by over a thousand guests, almost all of them in some way associated with research work. The gathering of distinguished visitors took place in a mammoth tent erected adjacent to the laboratories.

Eli Lilly, head of the Lilly organization, presided as chairman. Mr. J. K. Lilly, now chairman of the board of Eli Lilly and Company, responded briefly on "Research in Manufacturing Pharmacy." Mr. Lilly traced the progress of research in manufacturing from the time of his entrance into the organization with his father, who founded the Lilly organization in 1876, up to the present. Dr. Irving Langmuir, director of research for the General Electric Company, was the next speaker. He spoke on "The Unpredictable Results of Research."

The chairman then introduced Sir Frederick Banting, of the University of Toronto. Sir Frederick described "The Early History of Insulin."

Sir Henry Dale, director of the National Institute for Medical Research, London, and secretary of the Royal Society, was the last speaker on the program. He chose as his topic "Chemical Ideas in Medicine and Biology." Sir Henry spoke of the immediate objectives of research in such laboratories as those of Eli Lilly and Company, and of their natural and proper differences from those of the laboratories supported by academic or public endowment. It was his thought, however, that the differences in result for the progress of medical science are often more formal than real. He expressed the hope that the growth of cooperation between those working in these different spheres might yet bring to many the rather rare privilege that had come to him of migrating from one to the other and back again, and thus of knowing at first hand the best that each can offer.

According to Sir Henry, the change that has taken place in the scope of pharmacy has a revolutionary aspect. He cited the fact that not very many years ago it was predominately concerned with the traditional drugs that had come into use through empirical observation. Even though with the years had come additions, from time to time, the therapeutic outlook and attitude had changed but little for centuries. He pointed out that a beginning had been made by pharmacology toward rationalizing the use of those drugs in common use which had an action sufficiently definite to be susceptible to experimental analysis. The attitude of the physician and that of the investigator, in the opinion of the speaker, was, however, one of skeptical pessimism.

THE NEW LILLY RESEARCH LABORATORY AT INDIANAPOLIS

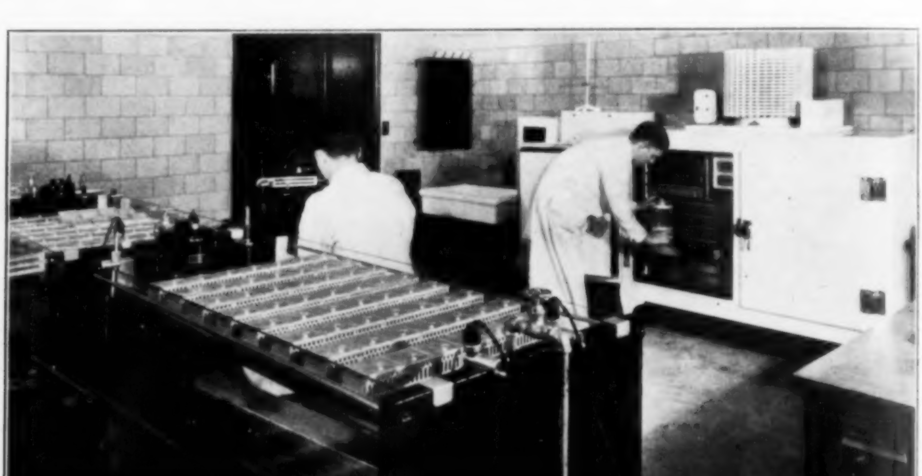
He did not suggest that palliative treatment no longer existed in medical practise or that its complete elimination was expected or even desirable. He cited the fact that alleviation of symptoms not only brings the richest reward of gratitude, but said that it might be the most urgent medical duty.

Sir Henry referred to the fact that he was speaking in the presence of Sir Frederick Banting and in the place where the large-scale production of insulin had its earliest organization, and that he felt he need not remind his audience of the revolutionary change which has taken place in the treatment of a disease that only a few short years ago was the despair of the physician.

Looking at the change as a whole one might distinguish two main contributory factors.

The first of these, in his opinion, was the recognition of infections as due to the invasion of the body by living microorganisms. He referred to the fact that it is a commonplace that preventive medicine was born of this discovery and that it gave a new direction to the therapeutics of infective diseases. He mentioned older remedies that owed their value to an unconscious application of such specific actions, for the control of infective organisms which modern research has since identified: cinchona, ipecac, mercury and the iodides. He contrasted these to the resources of modern therapeutics, with its range of antitoxins and bacterial products, its growing list of synthetic compounds discovered as a result of deliberate and organized research.

The second of these factors contributing to a change in outlook, according to Sir Henry, was the recognition of diseases due to the lack of substances normally present in the body. Modern therapeutics, in his opinion, can show no triumphs more brilliant than those which have followed the discovery of methods of preparing a number of glandular products in a state of sufficient purity to enable them, by artificial ad-



A PHARMACOLOGIC TESTING LABORATORY

WHERE THE STANDARDIZATION OF DIGITALIS, SQUILL, CONVALLARIA AND OTHER DRUGS OF SIMILAR NATURE IS DETERMINED. FROGS UNDER TREATMENT ARE PARTIALLY SUBMERGED IN CONSTANT-TEMPERATURE WATER BATHS IN SMALL INDIVIDUAL METAL BOXES SHOWN IN THE FOREGROUND.

ministration, to correct an abnormal deficiency.

He referred also to progress in the field represented by a second class of specifically acting substances, necessary like the hormones for healthy function and growth but obtained by the body mainly from food and known as vitamins.

Biochemistry, said Sir Henry, has long taken rank among the great divisions of science, while organic chemistry is showing a welcome tendency to recover its original objective, in studying the products and processes of living organisms.

The newer developments have but little relation to the art of the individual pharmacist whom our fathers knew, said the speaker, but we must resign ourselves as in other spheres of human activity to the loss of the individual art in exchange for scientifically organized production. In fact, he continued, in order to meet these novel, various and expanding demands of modern therapeutics, pharmacy has to become one of the most highly organized departments of scientific manufacture, covering an extraordinary range of expert knowledge and equipment. It now needs stables and pasturage, incubation rooms for large-scale culture of a wide variety of bacteria, and sterile rooms for manipulation of the products; chemical plant adapted to the difficult synthesis of complex and delicate compounds, or to the chemical and physical separation and purification of unstable natural principles, from animal organs only obtainable in adequate quantity and freshness by the cooperation of highly organized abattoirs. He cited, in addition, a much more fundamental requirement, calling particular attention to the need for research undertaken in the spirit of free inquiry, often with no immediate practical aim or any probable result other than the increase of fundamental knowledge.

The afternoon program was followed by an inspection of the new laboratories, the party being divided into small groups in the charge of guides. In the evening a banquet was tendered to the out-of-town guests. Mr. J. K. Lilly served as toastmaster and responses were made by Sir Henry Dale; Dr. Elliott P. Joslin, of Boston; Dr. George R. Minot, of Boston; Dr. Frank R. Lillie, of Chicago; Dr. George H. Whipple, of Rochester, N. Y.; Dr. Carl Voegtlin, of Washington, D. C., and Dr. G. H. A. Clowes, head of the Lilly Research Laboratories.

H. S. N.

SCIENCE AT THE CENTURY OF PROGRESS EXPOSITION IN 1934

A Century of Progress Exposition in 1934, as in the previous year, fulfilled its object of explaining the nature of the fundamental scientific discoveries of the past century and describing how they have been applied to the practical uses of men.

The Hall of Science, in which was portrayed the story of the contributions of science to mankind's advancement, was once more one of the most popular buildings in the exposition.

Again as in 1933 the main principles of mathematics, physics, chemistry, biology and geology were explained, with the purpose of making science a living thing to the layman. The progress of medical science and its contributions to human health and comfort were portrayed.

But important additions and improvements were made to the basic science exhibits to dramatize each phase so far as possible. Sound and light waves,

x-rays, liquid air, chemical processes, anatomy, geometric equations, disease prevention, physical phenomena, biological development and other phases were cleared of technical details and thereby were made more understandable to the lay visitor.

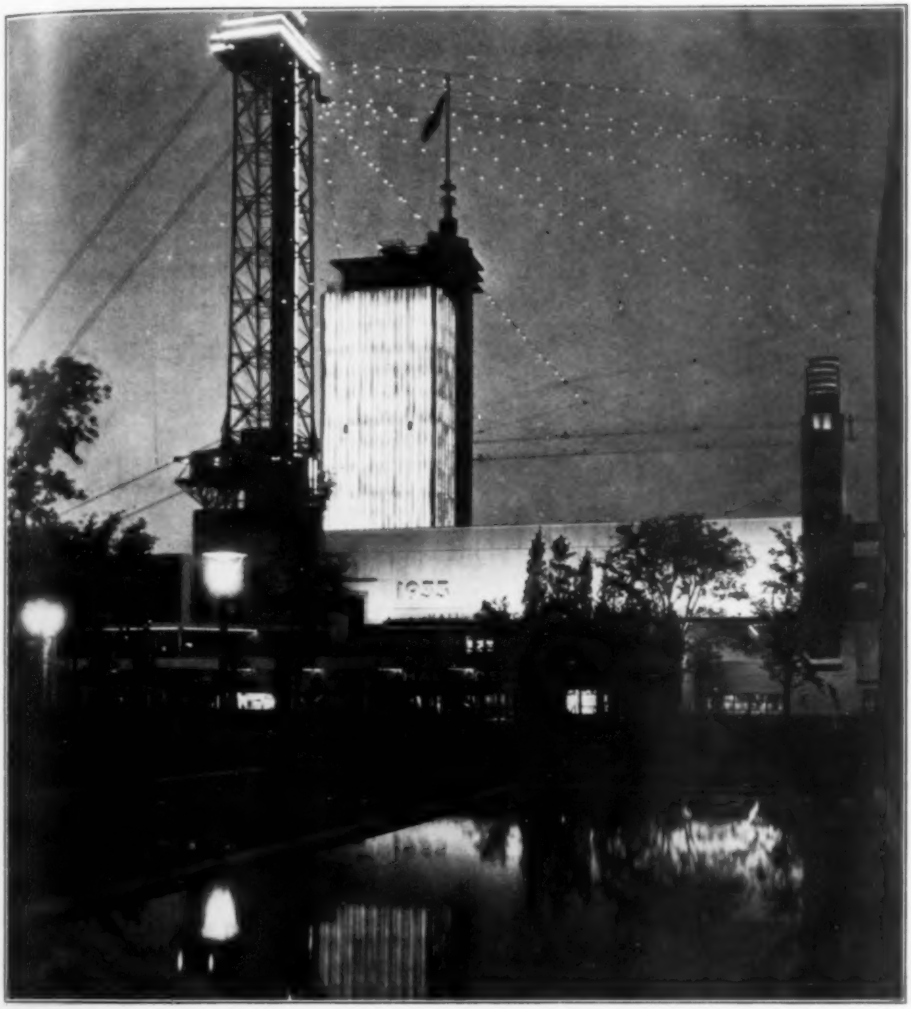
The exhibits in the Hall of Science gave even to the layman an increased appreciation of the fact that the different physical sciences are definitely interrelated and interdependent. Here was evidence that the basic sciences are dealing with different aspects of the same fundamental things. The sciences utilize each other's apparatus and conclusions and arrive by different routes at investigations of the same phenomena.

A perception of the correlation of all the sciences was given by eight exhibits in the Great Hall of the Hall of Science.

The Periodic Table of the Elements is an illuminated display of the ninety-two elements which constitute the earth and are the material with which all science works. The first periodic table of the elements was drawn up by the Russian chemist Mendeleeff in 1869. To-day all the ninety-two elements are known and have been fitted into their places in the series, chiefly by deliberate search along the lines indicated by the gaps in the original table.

Invisible radiation, the newest field of scientific work, is being studied by stratosphere balloon flights, which are exploring expeditions outside the living world. The gondola in which Auguste Piccard made the first stratosphere ascent in 1932 hangs above a skeleton frame like that of the sealed globe in which Lieutenant Commander T. G. W.

THE BUILDINGS AND GROUNDS OF A CENTURY OF PROGRESS



THE HALL OF SCIENCE WITH THE TOWER AND CABLES OF "SKY RIDE" IN THE FOREGROUND

Settle, U. S. N., and Major Chester L. Fordney, U. S. M. C., made their Century of Progress stratosphere ascension last year to a record height of 61,237 feet. In this framework the apparatus they carried for the study of the cosmic rays is to be seen. These are the most penetrating rays known. Our protection from them is our 50,000 feet of atmosphere, equal in protective power to two feet of solid lead.

The age and evolution of the earth were shown by the "Clock of the Ages," a giant dial representing the great eras of geologic time: Azoic, Archeozoic, Proterozoic, Paleozoic, Mesozoic and Cenozoic. As the revolving hand ticks off a second for each 10,000,000 years forty-two colored pictures are shown, representing the appearance of the earth and its inhabitants as the time advances. The time is almost run off before mam-

mals appear and man is on the scene in the last few seconds only.

A model of a molecule of common salt showed the structure of the atom. The smaller of the two spherical structures represented a positive ion of sodium, the larger a negative ion of chlorine. The number of white lights represented the number of electrons. The emptiness of the structure indicated the proportionate area occupied by the nuclei, of which, according to modern view, nearly all the mass of the atom is composed.

The gyroscopic compass, lent by the United States Navy, shows how this type of compass automatically aligns itself with the earth's axis and points true north and south, unlike the magnetic compass which does not indicate true north except in a few regions of the earth.

Conversion of electrical energy into mechanical energy is shown by an apparatus illustrating the operation of rotating magnetic fields.

The principle of cell growth is illustrated by a remarkable giant operating model of a basswood tree twig which "grows" from a three-year-old twig to a four-year-old twig in a few seconds by the multiplication of cells.

An interesting exhibit shows a sample of heavy water and the apparatus used to make it.

Thus around the Great Hall were arranged in series the exhibits of the basic sciences to show the definite accomplishments of science as they stand to-day and their application to the industries that supply the needs of civilization.

G. A. B.

DR. BERTHOLD LAUFER: AN APPRECIATION

Dr. Berthold Laufer, distinguished Orientalist, died suddenly on September 13, 1934. Dr. Laufer was born in Cologne, Germany, in 1874. After a course of general education at Cologne and Berlin he specialized in Oriental languages, receiving the Ph.D. at Leipzig in 1897. Coming to the United States in 1898, he became connected with the American Museum of Natural History, New York. This institution was then engaging in Asiatic researches. Laufer was given the leadership of the Jesup North Pacific Expedition to Saghalin Island and the Amur River region of eastern Asia for work on the ethnology of native tribes. He conducted the Jacob H. Schiff expedition to China for culture history investigations and collections, the material also coming to the American Museum. During his stay in New York he was lecturer on anthropology and East-Asiatic languages at Columbia University in Dr. Franz Boas's department. In 1908 he came to the Field Museum of Natural History, Chicago, and headed the Blackstone expedition to Tibet and China, meeting with success in obtaining great quantities of valuable material. The Captain Marshall Field expedition to China under Laufer's direction also produced notable scientific results. In 1915 Laufer became curator of anthropology in the Field Museum, a position which he held during the remainder of his life.

As a museum man Laufer ranked with the first in that science. The abundant and carefully collected material brought in by the various expeditions he directed was displayed in the best traditions of modern museum science. Viewing the Field Museum display of Asiatic art and technology it seems overwhelming that it could be the effort of one man. Laufer's knowledge and practise of museum science was displayed in all the branches of anthropology. He demonstrated

Keystone View Co.

BERTHOLD LAUFER

presentation of objects to the best advantage, with accurate labels and with all the accompaniments that would promote their value in teaching the public.

To scientific literature Laufer found time to make important contributions. On account of his thoroughness his writings will have a permanent value. He produced numerous books and over 200 monographs on ethnology, art, philology of Asia, histories of domestic animals and cultivated plants.

Among his general writings may be mentioned: "History of the Finger-Print System"; "The American Plant Migration"; "Tobacco and Its Uses in Africa"; "The Prehistory of Aviation"; "Geophagy." Important works on special subjects are: "Historical Jottings on Amber"; "The Diamond" (Chicago, 1915); "Notes on Turquoise in the East"; "Jade." Papers on the domestication of animals: "The Reindeer and Its Domestication"; "The Giraffe in History and Art"; "Insect Musicians and Cricket Champions of China"; "The Domestication of the Cormorant in China and Japan." Special monographs on linguistics and arts: "Dokumente der Indischen Kunst—Das Citralakshana nach dem Tibetischen Tanjur"; "Chinese Clay Figures"; "Prolegomena on the History of Defensive Armor"; "Chinese Grave-Sculptures of the Han Period"; "The Beginnings of Porcelain in China."

Dr. Laufer had by training as well as by natural ability a marked skill in acquiring languages, of which he had command of a respectable number. This

knowledge of languages stood him in good stead in the conduct of his expeditions to distant foreign countries. In Tibet, for example, there was required the native language as well as skilful diplomacy to collect cult objects from a hostile priesthood as well as to get them out of the country. Fortunately, Laufer had these qualifications in a marked degree.

In recognition of his attainments many honors were conferred on Dr. Laufer. He was collaborator of the U. S. Department of Agriculture, member of the National Research Council, member of the National Academy of Sciences, fellow of the Ethnological Society and of the American Anthropological Association, Oriental Society, Linguistic Society, Historical Science Society, Royal Asiatic Society, Shanghai, China; Royal Asiatic Society, London; Hakluyt Society; Société Asiatique de Paris; Société Linguistique de Paris; honorary member of the Archaeological Society of Finland; corresponding member, Finnish Society, Helsingfors; member, Society of Asiatic Art, the Hague. Much of Dr. Laufer's energy was devoted to editorial work in the department of anthropology in the Field Museum. He was also editor of the Boas anniversary volume.

As the Asiatic study unveils more and more of its vast congeries of subjects for investigation, the loss of a man of the superior attainments of Laufer seems irreparable. What we have left after the animating spark is extinct is the monument of his brilliant work that will remain as a source and a mark for emulation by future scholars.

In character Laufer was gentle and kind, always willing to help in a worthy cause. He impressed one as a serious scholar. Those who knew him had frequent evidences that he was wise in the lore of the ancient world, coming out in pithy epigrammatic sayings, sometimes a stream of them. His literary style was nearly perfect. The leaflets written by Laufer for the Field Museum of Natural History are among the best in popular science literature.

WALTER HOUGH
U. S. NATIONAL MUSEUM